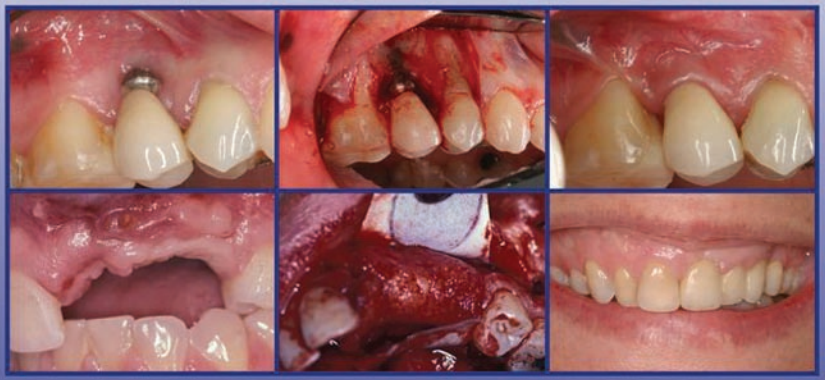
Dental Implant Complications

ETIOLOGY, PREVENTION, AND TREATMENT



Edited by

Stuart J. Froum

WILEY-BLACKWELL

Dental Implant Complications

Dental Implant Complications

Etiology, Prevention, and Treatment

Edited by

Stuart J. Froum, DDS, PC

Diplomate of the American Board of Periodontology
Diplomate of the International Congress of Oral Implantology
Clinical Professor and Director of Clinical Research,
Department of Periodontology and Implant Dentistry at
New York University College of Dentistry
Private Practice Periodontics and Implant Dentistry, New York, NY

WILEY-BLACKWELL

A John Wiley & Sons, Ltd., Publication

This edition first published 2010

Blackwell Publishing was acquired by John Wiley & Sons in February 2007. Blackwell's publishing programme has been merged with Wiley's global Scientific, Technical, and Medical business to form Wiley-Blackwell.

Registered office
John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, United Kingdom

Editorial offices
9600 Garsington Road, Oxford, OX4 2DQ, United Kingdom
2121 State Avenue, Ames, Iowa 50014-8300, USA

For details of our global editorial offices, for customer services and for information about how to apply for permission to reuse the copyright material in this book please see our website at www.wiley.com/wiley-blackwell.

Library of Congress Cataloging-in-Publication Data
Dental implant complications: etiology, prevention, and treatment/edited by Stuart J. Froum
p.; cm.
Includes bibliographical references and index.
ISBN 978-0-8138-0841-3 (hardback: alk. paper) 1. Dental Implants—Complications. I. Froum, Stuart J.
[DNLM: 1. Dental Implantation—adverse effects. 2. Dental Implants—adverse effects. WU 640 D4137 2010]
RK667.I45D457 2010
617.6′92—dc22 2009049785

A catalogue record for this book is available from the British Library.

Set in 9.5/12.5pt Palatino by Gray Publishing, Tunbridge Wells, Kent
Printed in Singapore

1 2010

Contents

List of contributors

Dario Adolfi DDS, CDT
DDS Degree at State University of São Paulo, Brazil
Ceramist and Dental Technician
Director of the Spazio Education in Dentistry,
São Paulo, Brazil

Daniel Buser DDS, Prof. Dr Med. Dent.
Professor and Chairman, Department of Oral Surgery and Stomatology, School of Dental Medicine, University of Bern, Switzerland

Bobby Butler DDS
Private Practice, Seattle, WA, USA
School of Dentistry, Affiliate Faculty, University of Washington, WA

John S. Cavallaro Jr. DDS
Private Practice, Prosthodontics & Surgical Implantology, Brooklyn, NY, USA
Associate Clinical Professor, Department of Periodontology & Implant Dentistry, New York University College of Dentistry, NY, USA
Member, Academy of Osseointegration
Fellow, Greater New York Academy of Prosthodontics, New York, USA

Stephen T. Chen BDS, MDSc, PhD
Senior Fellow, Periodontics, School of Dental Science, University of Melbourne, Parkville, Victoria, Australia

Sang-Choon Cho DDS
Assistant Clinical Professor
Associate Director of Clinical Research, Ashman Department of Periodontology and Implant Dentistry, New York University College of Dentistry, NY, USA

Donald S. Clem DDS, FACD
Diplomate, American Board of Periodontology
Assistant Clinical Professor, Loma Linda University School of Dentistry, Center for Oral Implants, Loma Linda, CA, USA
Adjunct Professor, Department of Periodontics, University of Texas at San Antonio, TX, USA

Steven E. Eckert DDS, MS, FACP
Professor of Dentistry, Department of Dental Specialties, Mayo Clinic College of Medicine, Rochester, MN, USA

Brian Ehrlich DDS
Clinical Assistant Professor, Department of Periodontology and Implant Dentistry, New York University College of Dentistry, New York, NY, USA

Abd Elsalam Elaskary BDS
Visiting lecturer New York University
Private Practice, Alexandria, Egypt

Nicolas Elian DDS
Assistant Professor, Head of Division
Director of Fellowship Program, Director of Experimental Research, Department of Periodontology and Implant Dentistry, New York University College of Dentistry, NY, USA
Adjunct Assistant Professor, Department of Periodontics, University of Pennsylvania School of Dental Medicine, PA, USA
Visiting Professor, University of Chietti, Italy, and Tong Ji University, China
Honorary Professor, El Instututo de Investigaciones Craneo Dento Maxilo Facial de la Facultad de Ciencias de la Salud, Argentina

Robert N. Eskow DMD, MScD
Clinical Professor, Department of Periodontology and Implant Dentistry, New York University College of Dentistry, NY, USA
Private Practice, Livingston & Clark, New Jersey, USA
Diplomate American Board of Periodontology, American Board of Oral Medicine

Cyril I. Evian DMD
Clinical Professor, Periodontics and Implant Dentistry, University of Pennsylvania, PA, USA
Diplomate, American Board of Periodontology

Filippo Fontana DDS, MS
Department of Implant Dentistry, School of Dentistry, Università degli studi di Milano, Fondazione IRCCS Ca' Grande, Milano, Italy
IRCCS Foundation Policlinico Hospital "Mangiagalli Regina Elena", Institute for Dental Research and Education

Scott H. Froum DDS
Clinical Associate Professor of Periodontology and Implant Dentistry, New York University College of Dentistry, NY, USA
Private Practice Periodontics and Implant Dentistry New York, NY

Stuart J. Froum DDS
Diplomate of the American Board of Periodontology
Diplomate of the International Congress of Oral Implantology
Clinical Professor and Director of Clinical Research, Department of Periodontology and Implant Dentistry, New York University College of Dentistry, NY, USA
Private Practice Periodontics and Implant Dentistry New York, NY

Jeffrey Ganeles DMD, FACD
Diplomate, American Board of Periodontology
Clinical Associate Professor, Nova Southeastern University, Ft Lauderdale, FL, USA
Periodontist, Florida Institute for Periodontics & Dental Implants, Boca Raton, FL, USA

Scott D. Ganz DMD, Maxillofacial Prosthodontist
Clinical Assistant Professor, Department of Restorative Dentistry, UMDNJ, New Jersey Dental School, Newark, NJ, USA
Clinical Attending, Hackensack University Medical Center, Hackensack, NJ
Private Practice, Fort Lee, NJ, USA

Charles J. Goodacre DDS, MSD
Dean and Professor of Restorative Dentistry, Loma Linda University, School of Dentistry, Loma Linda, CA, USA

Gary Greenstein DDS, MS
Diplomate of the American Board of Periodontology
Clinical Professor, Department of Periodontology & Implant Dentistry, New York University College of Dentistry, NY, USA
Private Practice, Freehold, NJ, USA

David Grossberg BDS FICD
Diplomate of the American Board of Periodontology
Specialist Clinical Associate, University of Sydney, Australia
Private Practice, Sydney, Australia

Ole T. Jensen DDS, MS
Private Practice, Greenwood Village, CO, USA
Visiting Professor, Hebrew University-Hadassah, Jerusalem, Israel

Mathew T. Kattadiyil BDS, MDS, MS
Associate Professor of Restorative Dentistry
Program Director, Advanced Education in Prosthodontics, Loma Linda University, School of Dentistry, Loma Linda, CA, USA

J. Daulton Keith DDS, FACD, FICD
Associate Professor of Implantology and Periodontics, School of Dentistry Medical University of South Carolina, SC, USA
Private Practice, Charleston, SC, USA

Geon U. Kim DDS, MS
Postgraduate Student in Implant Dentistry
Department of Periodontology and Implant Dentistry, New York University College of Dentistry, New York, NY, USA
Research and Lecture Coordinator, Vizstara and Vizstara Professional, Englewood Cliffs, NJ, USA

Niklaus P. Lang DMD, MS, PhD, Odont. dr. h.c. mult., Hon. FRCPS(Glasgow)
Professor Emeritus, University of Berne, Switzerland
Professor of Implant Dentistry, The University of Hong Kong, Prince Philip Dental Hospital, Sai Ying Pun, Hong Kong SAR, PR China

Burton Langer DMD, MSCD
Diplomate, American Board of Periodontology, Beth Israel Medical Center
Private Practice, New York, NY, USA

Laureen Langer DDS
Private Practice, New York, NY, USA

Jeffrey R. Lemler DDS
Associate Professor of Implantology and Periodontics, New York University College of Dentistry, NY, USA
Diplomate, American Board of Periodontics
Diplomate, International Congress of Oral Implantology
Private Practice, New York, NY, USA

Bradley S. McAllister DDS, PhD
Assistant Professor, Oregon Health Sciences University, OR, USA
Private Practice, Portland, OR, USA

Pamela K. McClain DDS
Diplomate, American Board of Periodontology
Assistant Clinical Professor, Department of Surgical Dentistry/Periodontology, University of Colorado School of Dentistry, CO, USA
Private Practice Limited to Periodontics, Aurora, CO, USA

Brian L. Mealey DDS, MS
Professor and Graduate Program Director, Department of Periodontics, University of Texas Health Science Center, San Antonio, TX, USA

Craig M. Misch DDS, MDS
Private Practice, Oral & Maxillofacial Surgery and Prosthodontics, Sarasota, FL, USA
Clinical Associate Professor, Department of Implant Dentistry, New York University College of Dentistry, New York, NY, USA

Isabella Rocchietta DDS
Department of Periodontology, Università degli studi Fondazione di Milano, IRCCS Ca' Grande, Milano, Italy
IRCCS Foundation Policlinico Hospital "Mangiagalli Regina Elena", Institute for Dental Research and Education

Louis F. Rose DDS, MD
Clinical Professor of Periodontics, University of Pennsylvania, School of Dental Medicine, Philadelphia, PA, USA
New York University, School of Dentistry, New York, NY, USA
Professor of Medicine & Surgery, Drexel University College of Medicine, Philadelphia, PA, USA
Private Practice, Philadelphia, PA, USA

Paul S. Rosen DMD, MS
Diplomate, American Board of Periodontology
Clinical Associate Professor, Department of Periodontics, Baltimore College of Dental Surgery, University of Maryland Dental School, Baltimore, MD, USA
Private Practice, Yardley, PA, USA

Edwin S. Rosenberg BDSH Dip. Dent., DMD, FICD, FACD
Diplomate of the American Board of Periodontology
Clinical Professor of Implant Dentistry and Periodontics, Clinical Professor of Surgical Sciences, Department of Periodontology and Implant Dentistry, New York University College of Dentistry, NY, USA
Professor of Implant Dentistry, Perio and Pros, Hebrew University, School of Dentistry, Jerusalem, Israel
Adjunct Professor of Medicine and Surgery, Department of Medicine and Surgery, Drexel University, Philadelphia
Clinical Professor and Consultant of Periodontics and Implant Surgery, Eastman Dental College, University College London

Thomas J. Salinas DDS, FACP
Associate Professor of Dentistry, Department of Dental Specialties, Mayo Clinic College of Medicine, Rochester, MN, USA

Oswaldo Scopin de Andrade DDS, MS, PhD
Master and PhD in Prosthodontics at State University of Campinas, São Paulo, Brazil
Advanced Post Graduated Program in Prosthodontics at New York University College of Dentistry, NY, USA
Director of the Advanced Program in Implant and Esthetic Dentistry, Senac University, São Paulo, Brazil

Massimo Simion MD, DDS
Chairman, Department of Periodontology, Università degli studi Fondazione di Milano, IRCCS Ca' Grande, Milano, Italy
IRCCS Foundation Policlinico Hospital "Mangiagalli Regina Elena", Institute for Dental Research and Education

J. Kobi Stern DMD, MSc
Diplomate, American Board of Periodontology
Assistant Professor, Department of Periodontics, Medical College of Georgia School of Dentistry, Augusta, GA, USA

Valerie Sternberg Smith RDH, BS
Clinical Instructor, Department of Periodontology and Implant Dentistry, New York University College of Dentistry, NY, USA
Private Practice, Livingston & Clark, New Jersey, USA
Member Academy of Osseointegration & American Dental Hygienists' Association

Dennis P. Tarnow DDS
Professor and Chair, Department of Periodontology and Implant Dentistry, New York University College of Dentistry, NY, USA

Thomas D. Taylor DDS, MSD, FACP
Professor and Head, Department of Reconstructive Sciences, University of Connecticut School of Dental Medicine, CT, USA

Maurizio S. Tonetti DMD, MMSc, PhD
Director, European Research Group on Periodontology (ERGOPerio), Brienz, Berne, Switzerland
Private Practice Limited to Periodontology, Genova, Italy

Jonathan Waasdorp DMD, MS
College of Dental Surgery, University of Maryland, Baltimore, MD, USA

Barry D. Wagenberg DMD
Associate Clinical Professor, Department of Periodontics and Implant Dentistry, New York University School of Dentistry, NY, USA
Director of Dental Education, Director of Periodontics, Newark Beth Israel Department of Dentistry, Newark, NJ, USA
Private Practice in Livingston and Roselle Park, NJ, USA

Stephen S. Wallace DDS
Fellow, Academy of Osseointegration
Clinical Associate Professor, Department of Periodontics, University of Maryland, MD, USA
Clinical Associate Professor, Department of Periodontics and Implant Dentistry, New York University, NY, USA
Private Practice of Periodontics, Waterbury, CT, USA

Thomas G. Wilson, Jr. DDS
Private Practice of Periodontics, Dallas, TX, USA

Edwin J. Zinman DDS, JD
Former Lecturer, UCSF Department of Periodontics
Present: Private Law Practice, San Francisco, CA, USA

Foreword

I am delighted to be asked to write the Foreword for this new book on implant complications. This book is greatly needed in dentistry, and quite frankly, is overdue. I am especially glad that Stuart Froum decided to undertake this work and to provide the dental profession with a much-needed resource in implant dentistry.

It is hard to believe that more than 30 years have gone by since Leonard Shulman and Paul Schnitman organized the landmark NIH–Harvard consensus development conference on dental implants. In June 1978 a group of clinicians and investigators assembled in Boston to examine the evidence that dental implants "work", and to the risks and benefits of placing dental implants, and the complications after implant placement. Although the conclusions at this conference were positive, those were nonetheless tentative days for the field of implant dentistry. We were still somewhat "flying by the seat of our pants" in the management of patients with dental implants. But clearly the field of implant dentistry has come a long way since that time. Over the ensuing 31 years we have seen implant designs greatly change so that now state-of-the-art root form implants are standard practice. We have watched as biomaterials engineers have perfected the surfaces of implants to foster maximum osseointegration between device and bone. Periodontal and oral surgeons have taught us how to gain bone in much-needed sites before implant placement by using bone grafts, membranes, signaling molecules, and novel surgical techniques. Restorative colleagues continue to teach us that in certain clinical situations dental implants can be restored and placed into function almost immediately, and if not immediately, very soon after implant placement. And now, to complicate things even more, we are learning that individuals with untreated periodontitis have a greater risk for certain systemic illnesses such as cardiovascular disease, diabetes, adverse pregnancy outcomes, and pulmonary disease. Thus, dentistry is asking: at what point should a tooth with advanced periodontitis be extracted and replaced with a dental implant?

In the past 15 years many excellent books on implant dentistry have been published. These books, by outstanding clinicians, cover many aspects of dental implants including introducing new concepts such as guided bone regeneration. But what is evident is that there has not been a focus on implant complications. Clearly, this is something that has been on people's minds for some time now. One cannot attend a conference on dental implants without hearing about the "growing problem" of implant complications due to the increase in the treatment of patients with dental implants. And so, Stuart Froum's book is very timely and much needed.

Froum has assembled an impressive group of players for this book. The list of authors reads like a Who's Who in implant dentistry. I am not sure how he got these outstanding clinicians to find the time to write for him, but he did. Equally impressive are the topics covered in this book. Froum has thought of it all. This book is a tremendous resource for patient management, with each chapter focusing on very specific issues that confront clinicians every day. The book concludes with world-class experts sharing examples of how they manage everyday complications.

All told, I say "lucky us". We now have a first rate book that provides the missing link in the multiple facets of management of patients with dental implants; that is, the management of complications. I look forward to the coming years in the development of the field of implant dentistry knowing that clinicians such as Stuart Froum and his colleagues will help continually advance this very exciting area of dentistry.

Ray C. Williams, DMD
Professor and Dean
School of Dental Medicine
Stony Brook University
Stony Brook, NY 11794, USA

Introduction

This book is written for any dentist placing and/or restoring implants. Its aim is to identify common and uncommon implant complications, discuss their etiology, and propose methods of prevention. Our hope is that by doing this the clinician will be better able to assess the risks of and avoid, or reduce, many of the complications being seen today. Moreover, the treatments of these complications are discussed in detail, so if the reader experiences a similar or related problem they will be familiar with possible treatment options. Often a minor (and more often a major) complication can result in anguish for the patient, associated with pain, loss of income, and loss of time, and for the clinician loss of a patient and/or referral.

The introduction of the concept of osseointegrated endosseous implants to the field of dentistry in the 1980s resulted in a paradigm shift that affected almost every aspect of dental care. Diagnosis and treatment planning now included an implant option in restorative dentistry, periodontics, oral surgery, endodontics, and orthodontics. High rates of implant survival increased the attractiveness of this option for patients and clinicians alike. The inclusion of implant therapy became part of the undergraduate and graduate dental school curriculum. A significant part of every dental meeting included new research, new equipment, new techniques, and new products related to implant therapy. Technology specific for implant therapy, i.e. diagnostic software, computer axial tomography (CAT), cone beam (CB) scans, and computer-aided systems to place and restore implants, made the implant option easier and more predictable. Associated products including bone grafts, bone substitutes, membrane barriers, machines to measure implant stability, Piezosurgery®, laser systems, and computer-generated guides provided dentists with methods to expedite the placement of implants. New protocols for implant placement and restoration shortened the time required for replacement of an extracted or missing tooth with an implant-supported restoration. However, as more dentists and patients chose the implant option, more complications and adverse events began to be recorded. Some of these complications were minor while others resulted in damage to the patient and failure of treatment. It is the aim of this book to help both the novice and experienced implant clinician avoid these problems and, if they occur, to teach the clinician how to treat or when to refer these complications for treatment.

For the sake of organization, this book has been divided into implant complications associated with the diagnosis, treatment planning, placement, restoration, and maintenance of implants. While this division is arbitrary, and many complications have multifactorial etiology, the intention of this book is to help identify the most common implant complications. Each chapter presents information that will familiarize the clinician with these complications and which will hopefully decrease the number and extent of future complications. Moreover, the management of these complications will be described in depth in an attempt to provide guidance and direction to the clinician when he or she experiences any of these problems.

Each chapter will also provide a detailed analysis of the etiology, prevention, and treatment of specific complications. The reader will find that some chapters will repeat information previously discussed relative to different complications (e.g. three-dimensional implant placement, use of CAT or CB scans for implant planning, prosthetic solutions to implant malposition, esthetic complications, and requirements for a successful implant restoration). However, this repetition, rather than being viewed as redundant, should be considered basic to the prevention or management of several different types of complications. Moreover, the different authors present this information from various aspects of their clinical experience. This results in a more comprehensive understanding of a problem and actually increases knowledge of treatment options. Also included are chapters discussing complications that may occur from various site development procedures designed to augment hard or soft tissue before, or in conjunction with implant placement. Each chapter concludes with "Take-home tips", serving as helpful reminders in avoiding or treating the complications discussed in the chapter. In addition, there is a chapter on "Medicolegal issues related to implant

complications", discussing implant procedures relative to the law. Following the format of the book, this chapter discusses methods of avoiding legal ramifications of implant complications and discusses what to do if a clinician is involved in legal action.

Lastly, the chapter on "Management of implant complications by the experts" is a series of case reports by a number of experienced clinicians who review a specific complication, describe how they treated it, and discuss how they may have prevented it from occurring given similar circumstance. Each chapter should serve as a practical clinical guide.

To quote Barry Le Patner: "Good judgment comes from experience, and experience comes from bad judgment."* Hopefully, the reader will gain good judgment from the experience of the contributing authors of this book.

I would also like to thank and acknowledge the work of Felix van Dijk and Shirleen Go, who helped organize the chapters, figures, and references from the various chapter submissions.

Stuart J. Froum

*Quoted in *1,911 Best things anybody ever said*, compiled by Robert Byrne.

Chapter 1

Implant complications: scope of the problem

Stuart J. Froum DDS

Introduction

The introduction of endosseous dental implants as an option for restoring partially and fully edentulous patients has revolutionized dental treatment. High survival rates reported for single and multiple missing tooth replacements have validated the use of implant-supported restorations as a predictable method for oral rehabilitation (1–9). In fact, owing to the improved function provided by implants, the Toronto Consensus Conference concluded that a two-implant-supported overdenture should be considered the standard of care (replacing the full denture) for mandibular edentulous patients (10).

Implants enable a single missing tooth to be replaced without restoring adjacent teeth. In addition, implants allow fixed restorations to be fabricated in patients who are fully or partially edentulous. Thus, the National Institutes of Health, Consensus Development Conference Statement in 1978 on Dental Implant: Benefits and Risk concluded that, "clinically, thousands of patients have been treated with dental implants for years and there is no question that many received long-term benefits". However, the report further stated that, "some implants, fail in patients within six months; and some have resulted in extensive bone loss and produced irreversible defects and complications" (11). Although this report is more than 30 years old, and refers to different types of implant systems than those that are currently being used, problems with implant complications have grown in number and complexity. This is reflected in the increased number of articles, journals, and continuing education conferences that have recently been devoted to the topic of implant complications (4, 12–28).

Two recent literature reviews reported that when implant success was defined as an implant-retained restoration free of complications, only 61% of patients after 5 years with implant support fixed partial dentures (FPDs) (27) and 50% of patients after 10 years with combined tooth/implant FPDs (28) reported no complications.

Moreover, the prevalence of complications increased dramatically in some categories. In the latter study, for example, in terms of technical complications, the incidence of connection-related complications (screw loosening or fracture) rose from 4.3% after 5 years to 26.4% after 10 years. Of the 9% of restorations that were cemented, loss of retention of the restorations occurred in 6.2% within 5 years and 24.9% within 10 years (19). Obviously, implant complications increase with the length of time an implant-supported restoration is in place.

This book addresses the various complications with respect to their etiology, prevention, and treatment. Following a similar "Etiology, Prevention, and Treatment" format, this chapter addresses the scope of the problem regarding implant complications.

Etiology

There are several reasons for the increased number of implant complications being experienced by clinicians in recent years. First, the total number of implants being placed has increased significantly over the past 10–15 years. The 2000 Survey of Current Issues in Dentistry published by the American Dental Association noted that over a 4-year span (1995–1999) the average number of implants placed by all dentists annually increased from 37.7 to 56.2 (29). A dental implant overview evaluating the implant market by the Millennium Research Group in 2006 reported that from 2002 to 2006 the number of professionally active general practitioners rose from 125 230 to 130 830. During the same period the percentage of general practitioners rose from 5.0% to 19.0% (30). As the number of general practitioners was increasing, the actual number of general practitioners placing implants in 2006 was four times higher than the number placing implants in 2002. In the years 2003, 2004, 2005, and 2006 the growth in the number of implants placed by general practitioners was 82%, 46.0%, 24.4%, and 20.1%, respectively. The Millennium Research Group reported that, "Global sales of dental implant systems … are expected to maintain double digit growth over the next five years soaring to more than 4.5 billion dollars" (31). Therefore, the increased numbers of implants and

implant-related procedures being performed would have in itself resulted in a greater number of complications even if the percentage of adverse event occurrences remained the same.

The second reason is related to the fact that the increased number of implants being placed also reflects an increased number of dentists, varying in their clinical experience, placing and restoring implants. When first introduced to the profession, endosseous dental implants were primarily placed by oral surgeons and periodontists who had prior experience and training in bone and soft-tissue surgery. However, as the number of dentists placing implants increased, more dentists, who did not routinely perform oral or periodontal surgery, began performing additional procedures as part of implant therapy. Regrettably, in some cases this has resulted in an increased rate of implant-related complications.

A third reason for the increased incidence of complications is related to the fact that until recently, there were few formal training courses in implant placement or restoration for dental students during their 4-year dental education (29). Furthermore, the majority of that training was didactic in nature and did not include clinical experience with implant placement and restoration. From another perspective, many clinicians currently receive their implant training from continuing education courses offered by implant companies or private practitioners. These courses are less comprehensive than formal training programs and do not enable the participating dentist to become familiar with the breadth of complications that can occur.

The fourth reason for the increase in complications seen today is that dentists are placing implants in compromised sites using more aggressive protocols. Protocols today include implants placed at the same visit as tooth extraction, immediate provisionalization of the implant following placement, and in many cases the occlusal loading of an implant on the day of placement. Moreover, implants are being placed in compromised patients and/or in compromised sites where there is inadequate bone and soft tissue to fully emerge the implant (32). Many of these sites require augmentation procedures before implant placement. Implants being placed in these augmented sites or with these aggressive protocols require more experience and skill than are required for routine implant placement. These added procedures, combined with the more aggressive implant protocols, provide more opportunities for complications to occur. An often quoted statement related to complex cases is: "The more complicated the case the more potential for complications." When these complications arise, many dentists placing and/or restoring implants have little or no experience on how to handle the problem. The value of experience was recently demonstrated by a pilot for US Airways. On January 15, 2009, US Airways flight 1549 took off from La Guardia Airport in New York City. After several minutes in flight a flock of birds collided with the engines and both engines shut down. The pilot, Chesley Sullenberger, could not return to La Guardia airport or fly to a nearby airport to land the plane, which had completely lost power. Instead, he safely landed the plane on the Hudson River, thus saving all 155 people aboard. When asked how he managed to do this, Mr Sullenberger replied: "For 42 years, I had made small, regular deposits of education, training, and experience and the experience balance was sufficient that on January 15th, I could make a sudden, large withdrawal" (33).

Regrettably, many dentists placing implants today lack the education, training, and experience to make that "withdrawal"; in other words, to know what to do if and when an implant complication occurs.

The fifth reason for the increased incidence of implant complications indirectly arises from the lectures and courses that dentists attend. These courses frequently cite the high implant success rates reported in the literature. Although it is true that the survival rates of endosseous implants have been documented to be high (in the 90th percentile), a number of factors must be understood about the studies on which these data are based. First, in almost all cases the authors and investigators involved in the study were experienced surgeons or restorative dentists who were very familiar with implant placement, implant restoration, and the implant system that was used. In addition, the patient inclusion and exclusion criteria for these studies were usually very strict, resulting in exclusion of patients and sites that presented with high risk. Moreover, implant technology is changing so rapidly that the specific design and surfaced implants that were used and reported on in those studies are probably not available from the same company today. Newer implant surfaces on currently available implants may show improved results (more rapid integration or greater implant to bone contact) but lack the long-term data of the implants originally studied and reported on. Therefore, long-term data for many implants currently being used are limited as to the number and the length of time for which these "new" implants have been studied (Table 1.1). In an article reviewing different implant surfaces, the authors stated, "… many clinically well documented oral implant systems have largely been abandoned for the potential benefit of new, untested devices" (43). Another misconception arises when lecturers speak of implant "success", as opposed to implant survival. Traditionally, according to the literature, implant success was defined as an implant with no pain, no mobility, no radiolucent peri-implant areas, and minimum bone loss of less than 0.2 mm annually following the first year of loading (44). Roos-Janasaker added to this definition by further defining a successful implant as one that loses no more than

Table 1.1 Implant survival data with different implant systems

Company	Surface	Published study	Patients (*n*)	Implants (*n*)	Follow-up	Implant survival (%)
Nobel	TiUnite	Payne (34)	40	60	64 months	90
	Active					
Biomet 3i	Nanotite[a]	Biomet 3i	664	1057	Not shown	98.8
	Osseotite	Stach, meta-analysis (35)	931	2236	72 months	98.3
Straumann	SLA	Buser, 1997 (5)				
	SLActive	Payne (36)	12	24	52 weeks	91.6
Neoss	Multiple blasting	Andersson (IL case) (37)	33	141	6 months–3 years	96.5
		Zustein (38)				
		No GBR	50	57	1–3 years	98.2
		GBR		126	1–3 years	94.4
Biohorizons	LaserLok	Pecora (53)	15	20	1–37 months	100
Zimmer	RBM	NA				
Ankylos	RBM	Doring (39)	Not shown	275	8 years	98.2
Southern	RBM	Payne (34)		57		72
		Tawse-Smith (40)	12	24	12–52 months	100
Astra	TiOblast	Astrand (41)	66	184	12 months	95.5
		Cooper (42)	47	53	12 months	96.2

[a] Follow-up period is not shown. Failure occurred at 4 and 7 months.
[b] Neoss surface: dual blasting by ZrO- and Ti-based particle.
GBR = guided bone regeneration; NA: not available.

1.0 mm of bone of bone during the first year postplacement (45). Today the parameters for implant success also include the esthetic appearance of the final implant restoration. Many lecturers, sponsored by specific implant companies, will show their most successful esthetic cases that were accomplished using the sponsor's implant system. Few failures or complications are seen in these presentations. Few in the audience may realize that, as is done in well-controlled research studies, the selection of patients (and implant sites) was carefully screened when a successful case is being shown (see Chapters 8, 11, and 12). Rarely does the audience see a flawed response, and even less often, a complication. Thus, in clinical practice, when "things go wrong" and complications occur or when a clinician's results are not similar to what was shown in the lecture or symposium, the dentist, who was impressed by the "simplicity" and "reliability" of the implant system he or she purchased, is now at a loss as to what to do to rectify the unanticipated problem.

Anyone placing or restoring implants must be prepared for the possibility of potential complications. These may be minor or major, reversible or irreversible in nature. Some of the problems that we are seeing with implant complications today include implant failure, (Fig. 1.1a, b) malposed or non-restorable implants (Fig. 1.2) (see Chapter 25), peri-implantitis (Fig. 1.3a, b), esthetic implant failures (Fig. 1.4), and implants causing permanent damage to vital structures or teeth (Figs 1.5, 1.6) (i.e. sensory damage, damage to adjacent teeth, sinus complications, and loss of bone and soft tissue when implants fail or require removal). These adverse events are a growing concern to the dental community.

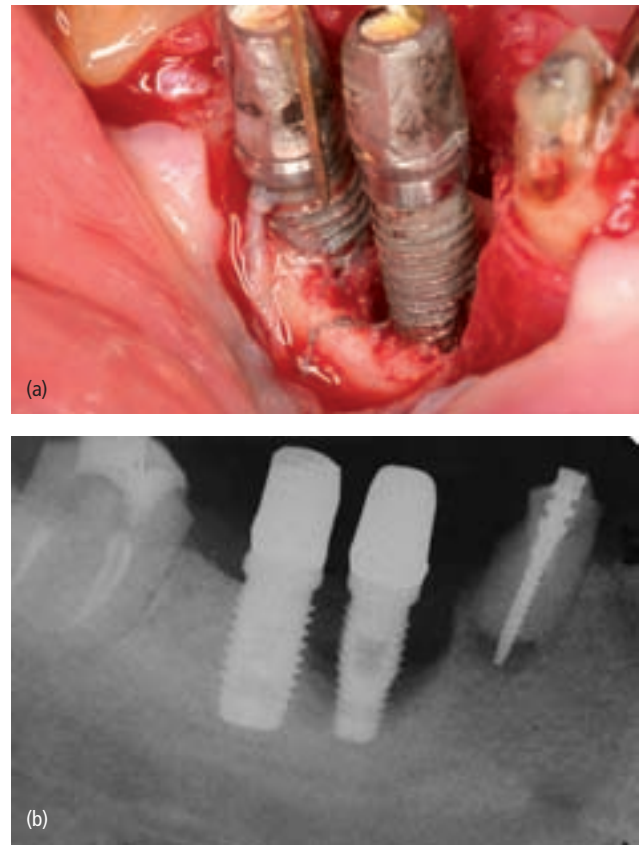


Fig. 1.1 (a) Clinical photograph of hopeless implant no. 29, bone loss around implant no. 30 and hopelessly involved tooth no. 28; (b) radiograph of implants seen in (a).

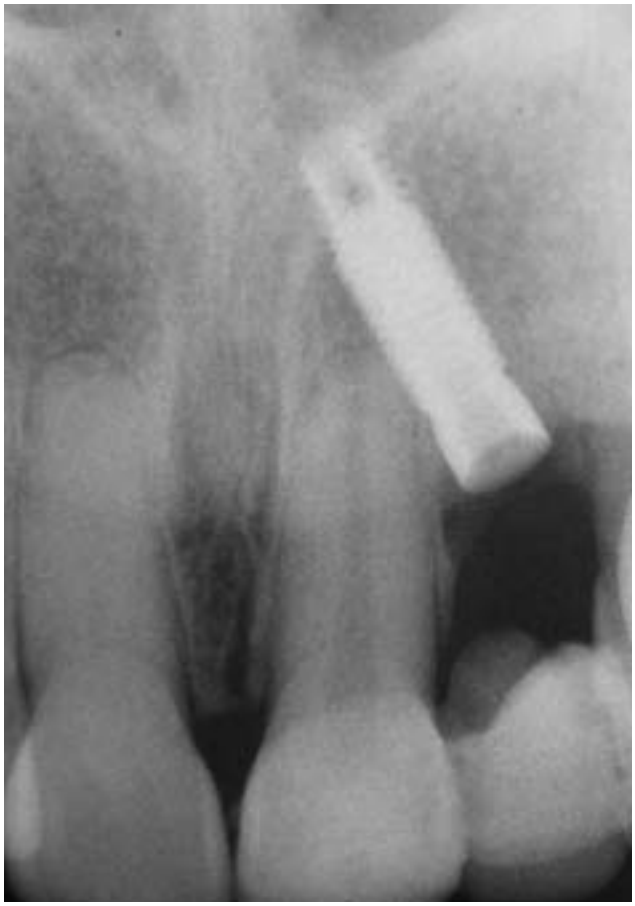
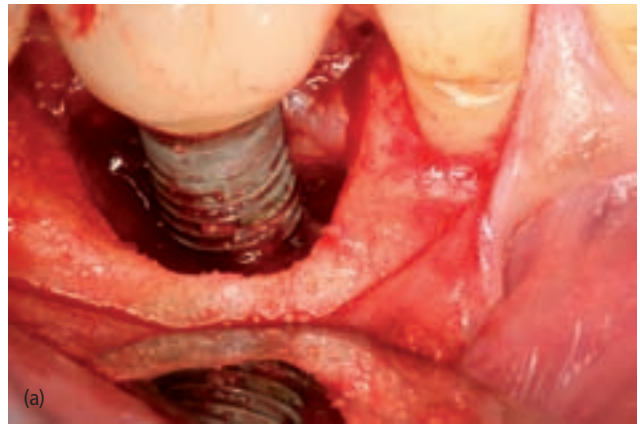


Fig. 1.2 Periapical radiograph of malposed maxillary left lateral incisor implant.



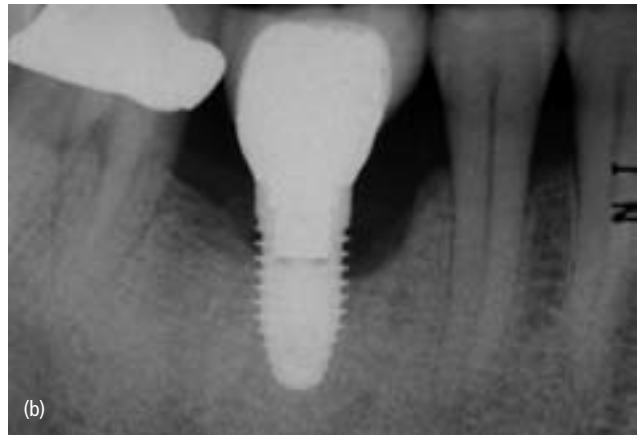


Fig. 1.3 (a) Clinical photograph of implant affected by peri-implantitis (note circumferential bone loss); (b) periapical radiograph of implant in (a).

The following observations and advice regarding implant complications, their etiology and sequelae as they relate to medicolegal issues are offered by Mr Art Curley, who is a senior trial attorney in the San Francisco-based health-care defense firm of Bradley, Curley, Asiano, Barrabee & Gale PC.

> "Dental implant related technology has evolved geometrically over the last 30 years to the point that the occurrence of complications and failures, once considered risks in the 1970s, may now be used as evidence of negligent care (legally: failure to meet the standard of care) for which the practitioner may be held liable.
>
> "Recently a boarded specialist placed an implant in contact with the inferior alveolar nerve (IAN) resulting in significant chronic and untreatable pain. Plaintiff's attorney sent the client for 3D scan which confirmed the implant as being in the IAN canal. That image begged the question, if, post-op, an imaging system can show exactly where the implant is, why wasn't one either taken and used or at least offered to the patient prior to surgery to prevent nerve damage? The result was a verdict of $1,300,000.

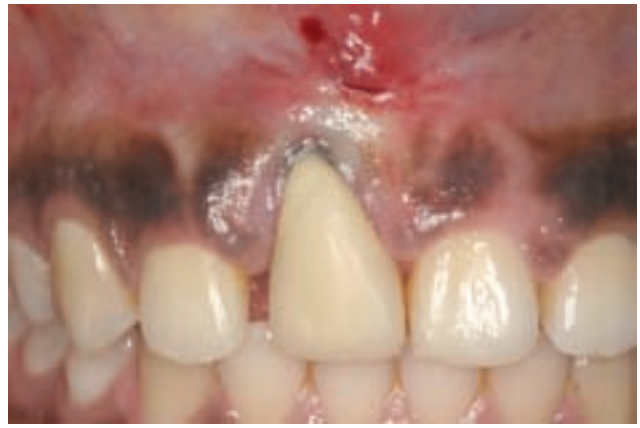


Fig. 1.4 Poor implant esthetics on the right implant-supported central incisor crown.

> At the time of this publication, a similar case is pending, with similar facts in a similar venue with a demand of $2,000,000."

Thus, a potential and undesirable result of these increased complications is that malpractice claims and therefore malpractice insurance premiums may eventually become so expensive for dentists utilizing implant

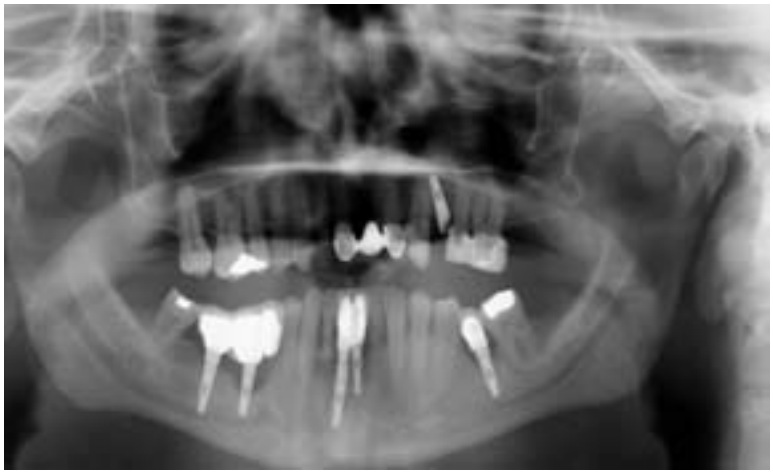


Fig. 1.5 Mandibular right distal implant impinging on the inferior alveolar nerve.

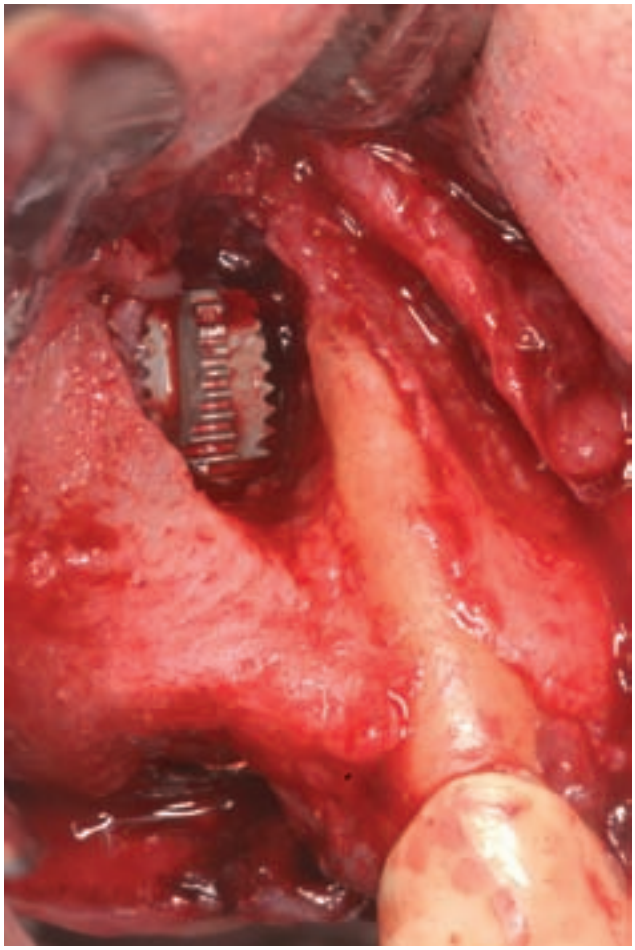


Fig. 1.6 Poorly positioned implant hitting the adjacent natural tooth.

restorations, so as to limit the use of implants as a restorative option (not unlike what occurred with obstetricians, many of whom stopped delivering babies). Lastly, with increased problems resulting from implant complications, third party regulation may become more restrictive as to when and where implants may be used.

Prevention and treatment

Most problems may be avoided if the implant companies promote, and clinicians adhere to, good clinical practice. This includes better and more comprehensive training for clinicians. Moreover, as the code of ethics prescribes (Section 2. Principle: Non-malfeasance, "do no harm"), under this principle "the dentist's primary obligations include keeping knowledge and skills current (and) knowing one's own limitations" (46). In addition, both dentists and implant companies should adhere to responsible advertising to avoid unrealistic expectations by clinicians and patients as to what implants can and cannot accomplish for specific problems. Better informed consent and communication among dentist, patient, and laboratory is essential to prevent unrealistic expectations for implant-supported restorations (see Chapter 24). In many cases an uncooperative or non-compliant patient may be the cause of a complication. Many patients refuse the presented plan or "insist" on treatment that exposes the practitioner and patient to greater risk. To prevent this, Mr Curley advises dentists to consider the doctrine of "informed refusal".

According to Mr Curley, that rule of law holds that a patient must be told in lay language the risks of not following the referral, recommendation or advice of a doctor, including the risks associated with selecting a less than ideal treatment, test or procedure.[1] Typical jury instruction risk management dictates that giving such

[1] CACI 535 A [*insert type of medical practitioner*] must explain the risks of refusing a procedure in language that the patient can understand and give the patient as much information as [he/she] needs to make an informed decision, including any risk that a reasonable person would consider important in deciding not to have a [*insert medical procedure*]. The patient must be told about any risk of death or serious injury or significant potential complications that may occur if the procedure is refused. A [*insert type of medical practitioner*] is not required to explain minor risks that are not likely to occur.

warnings and obtaining "informed refusal" should be documented. Note that most dental malpractice insurance carriers and some dental societies have developed "informed refusal" forms for their members (see Chapter 24).

Other "preventive" measures to reduce complications would include clinicians attending courses and reading publications that include information on treatment planning and case selection designed to minimize risk.

With respect to some complications, their incidence of occurrence has not been well documented. For example, the prevalence of peri-implantitis was unknown until recently because most papers reviewed in the State of the Science on Implant Dentistry "did not include this parameter" (47). Therefore, many patients and clinicians were not aware of this risk. However, recent studies show that this risk should be of concern and patients must be made aware of this before accepting the implant option. In two cross-sectional studies reported by Lindhe and Meyle, the incidence of peri-implantitis in the two groups of patients was 28% and ≥ 56% of the subjects and in 12% and 43% of implant sites, respectively (22). Therefore almost 25–50% of patients receiving implants experienced this complication. Knowledge regarding the etiology, prevention, and treatment becomes extremely important (see Chapter 7). The importance of a complication (e.g. sinus perforation) to the survival of the implant is an issue that is far from equivocal. While several authors found no correlation between sinus membrane perforation (SMP) and implant survival (48, 49), others show a direct link between SMP and complications including a lower implant survival rate (50, 51). In all cases treatment of the perforation becomes paramount (see Chapter 16). Therefore, any clinician performing a sinus augmentation should be familiar with the etiology and treatment of this complication.

The "treatment" of the problem of an increasing incidence of complication occurrence is ironically in the "prevention" of these problems from occurring. Better case selection, knowledge of systemic problems that can result in complications, and better treatment planning are all essential to reduce the risk of complications (see Chapters 2 and 3). Use of available technology and diagnostic tools, i.e. computer axial tomographic (CAT) scans, cone beam (CB) scans, surgical guides, computer treatment planning, and aids to assess primary implant stability (i.e. Periotest, Osstell), along with piezoelectric surgical machines, can aid the clinician in obtaining more predictable planning, placement, and restoration of implant-supported restoration.

Finally, knowledge, learning, and experience are paramount to reducing the number of and severity of complications that will inevitably occur. Unfortunately, the statement "the trouble with using experience as a guide is that the final exam often comes first and then the lesson" (52) is often quoted and all too true. However, by reading about the various complications in the ensuing chapters of this book, hopefully, the clinician placing and restoring implants can less painfully, and vicariously receive some valuable experience.

Moreover, the different authors will present this information from various aspects of their clinical experience. This should result in more comprehensive understanding of a problem.

Acknowledgment

The author would like to thank Mr Art Curley, Assistant Professor of Dental Jurisprudence at the Arthur A. Dugino School of Dentistry, for his advice and expertise on portions of this chapter related to medicolegal problems and implant complications.

References

1. Adell R, Lekholm U, Rockler B, Brånemark PI. A 15 year study of osseointegrated implants in the treatment of the edentulous jaw. *Int J Oral Surg* 1981; **10**: 387–416.
2. Adell R, Eriksson B, Lekholm U, Brånemark P-I, Jemt T. A long-term follow up study of osseointegrated implants in the treatment of totally edentulous jaws. *Int J Oral Maxillofac Implants* 1990; **5**: 347–59.
3. Albrektsson T, Dahl E, Enbom L, Engevall S, Engquist B, Eriksson AR, *et al*. Osseointegration oral implants: Swedish multicenter study of 8139 consecutively inserted Nobelpharma implants. *J Periodontol* 1988; **59**: 287–96.
4. Bashutski JD, Wang HL. Common implant esthetic complications. *Implant Dent* 2007; **16**: 340–8.
5. Buser D, Mericske-Stern R, Bernard JP, Behneke A, Behneke N, Hirt HP, *et al*. Long term evaluation of non-submerged ITI implants. Part 1: 8 year life table analysis of a prospective multi-center study with 2359 implants. *Clin Oral Implants Res* 1997; **8**: 161–72.
6. Jemt T, Lekholm U, Ragnar A. Osseointegrated implants in the treatment of partially edentulous patients: a preliminary study on 876 consecutive placed fixtures. *Int J Oral Maxillofac Implants* 1989; **4**: 211.
7. Lindquist LW, Carlsson GE, Jemt T. A prospective 15-year follow-up study of mandibular fixed prostheses supported by osseointegrated implants. *Clin Oral Implants Res* 1996; **7**: 329–36.
8. Van Steenberghe D, Quirynen M, Calberson L, Demanet M. A prospective evaluation of the fate of 697 consecutive intraoral fixtures and modem Brånemark in the rehabilitation of edentulism. *J Head Neck Pathol* 1987; **6**: 53–8.
9. Wennstrom JL, Ekestubbe A, Grondahl K, Karlsson S, Lindhe J. Implant-supported single-tooth restorations: a 5 year prospective study. *J Clin Periodontol* 2005; **32**: 567–74.
10. Feine JS, Carlsson GE, Awad MA, Chehade A, Duncan WJ, Gizani S, *et al*. McGill consensus statement on overdentures. *Int J Oral Maxillofac Implants* 2002; **17**: 601–2.

11. Dental implants: benefit and risk. *NIH Consensus Statement*, June 13–14, 1978; 1(3): 13–19.
12. Plan B: Negative outcomes, complications and failures in periodontal and implant therapy. In: *34th Annual USC International Periodontol and Implant Symposium*. January 23–24, 2009, Los Angeles, California.
13. Annibeli S, Ripari M, La Monaca G, Tonoli F, Cristalli MP. Local accidents in dental implant surgery: prevention and treatment. *Int J Periodontics Restor Dent* 2009; **29**: 325–31.
14. Chung DM. Oh Tae-Ju, Lee Jungwha, Misch CE, Wang HL. Factors affecting late implant bone loss; a retrospective analysis. *Int J Oral Maxillofac Implants* 2007; **22**: 117–26.
15. Greenstein G, Cavallaro J, Romanos, Tarnow D. Clinical recommendations for avoiding and managing surgical complications associated with implant dentistry: a review. *J Periodontol* 2008; **79**: 1317–29.
16. Huyah-Ba Guy, Friedberg JR, Vogratzi D, Ioannidou E. Implant failure predictors in the posterior maxilla: a retrospective study of 273 consecutive implants. *J Periodontol* 2008; **79**: 2256–61.
17. Jung RE, Pjetursson BE, Glauser R, Zembic A, Zwahlen M, Lang NP. A systematic review of the 5 year survival and complication rates of implant-supported single crowns. *Clin Oral Implants Res* 2008; **19**: 119–30.
18. Karbach J, Callaway A, Kwon YD, d'Hoedt B, Al-Nawas B. Comparison of five parameters as risk factors for peri-mucositis. *Int J Oral Maxillofac Implants* 2009; **24**: 491–6.
19. Lang NP Pjetursson BE, Tan K, Bragger U, Zwahlen M. A systemic review of the survival and complication rates of fixed partial dentures (FPDs) after an observation period of at least 5 years. II. Combined tooth-implant-supported FPDs. *Clin Oral Implant Res* 2004; **15**: 643–53.
20. Leonhardt A, Renvert S, Dahlen G. Microbial findings at failing implants. *Clin Oral Implants Res* 1999; **10**: 339–45.
21. Leonhardt A, Renvert S, Dahlen G. Five-year clinical, microbial and radiological outcome following treatment of peri-implantitis in man. *J Periodontol* 2003; **74**: 1415–22.
22. Lindhe J, Meyle J. Peri-implant diseases: Consensus Report of the Sixth European Workshop on Periodontology. *J Clin Periodontol* 2008; **35** (Suppl 8): 282–8.
23. Mardinger O, Obard S, Manor Y, Nissan J, Chaushu G. Factors affecting the decision to replace failed implants: a retrospective study. *J Periodontol* 2008; **79**: 2262–6.
24. Misch K, Wand HL. Implant surgery complications: etiology and treatment. *Implant Dent* 2008; **17**: 159–68.
25. Nedir R, Bischof M, Szmukler-Moncler S, Belsen UC, Samson J. Prosthetic complications with dental implants: from an up-to-8 year experience in private practice. *Int J Maxifillofac Implants* 2006; **21**: 919–28.
26. Park SH, Wang HL. Implant reversible complications: classification and treatments. *Implant Dent* 2005; **14**: 211–20.
27. Pjetursson BE, Tan K, Lang NP, Brägger U, Egger M, Zwahlen M. A systematic review of the survival and complication rates of fixed partial dentures (FPDs) after an observation period of at least 5 years. *Clin Oral Implant Res* 2004; **15**: 625.
28. Serrano E, Cautria R, Lopez M-G. A multi-center retrospective study of lost implants. *Rev Esp Cirug Oral Maxillofac* 2006; **28**: 339–48.
29. *2000 Survey of current issues in dentistry surgical dental implants.* American Dental Association, February 2, 2002. ISBN 0-910074-44-5.
30. US Dental Implant Market. Exhibit 2-2. *Dental implant market by segment* (US) (USA) 2004–2010: 8–12. Millennium Research Group, 2006.
31. *Implant-based dental reconstruction: the worldwide dental implant and bone growth market*, 2nd edn. Kalorama Information, May 18, 2007.
32. Oral implants in compromised patients. In: van Steenberghe D, ed. *Periodontology 2000*, Vol. 33. Oxford: Blackwell Munksgaard, 2003.
33. *New York Post*, February 10, 2009.
34. Payne AG, Tawase-Smith A, Thomson WM, Duncan WD, Kumara R. One-stage surgery and early loading of three implants for maxillary overdentures: a 1-year report. *Clin Implant Dent Relat Res* 2004; **6**: 61–74.
35. Stach RM, Kohles SS. A meta-analysis examining the clinical survivability of machined-surfaced and osseotite implants in poor-quality bone. *Implant Dent* 2003; **12**: 87–96.
36. Payne AG, Tawase-Smith A, Thomson WM, Kumara R. Early functional loading of unsplinted roughened surface implants with mandibular overdentures 2 weeks after surgery. *Clin Implant Dent Relat Res* 2003; **5**: 143–53.
37. Andersson P, Verrochi D, Pagliant L, Sennerby L. Immediate/early loading of Neoss implants. Preliminary results from an ongoing study. *Appl Osseointegr Res* 2008; **6**: 27–30.
38. Zustein T, Billistrom C. A retrospective follow-up of 50 consecutive patients treated with Neoss implants with or without an adjunctive GBR-procedure. *Appl Osseointegr Res* 2008; **6**: 27–30.
39. Doring K, Eisenmann E, Stiller M. Functional and esthetic considerations for single-tooth ankylosimplant-crowns: 8 years of clinical performance. *J Oral Implant* 2004; **30**: 198–209.
40. Tawse-Smith A, Payne AG, Kumara R, Thomson WM. Early loading of unsplinted implants supporting mandibular overdentures using a one-stage operative procedure with two different implant systems: a 2-year report. *Clin Implant Dent Relat Res* 2002; **4**: 33–42.
41. Astrand P, Engquist B, Dahlgren S, Engquist E, Feldmann H, Grondahl K. Astra Tech and Brånemark System implants: a prospective 5-year comparative study. Results after one year. *Clin Implant Dent Relat Res* 1999; **1**: 17–26.
42. Cooper L, Felton DA, Kugelberg DF, Chaffee N, Molina AL, Moriarty JD, *et al.* A multicenter 12-month evaluation of single-tooth implants restored three weeks after 1-stage surgery. *Int J Oral Maxillofac Implants* 2001; **16**: 182–92.
43. Albrektsson T, Wennerberg A. Oral implant surfaces: Part 2. Review focusing on clinical knowledge of different surfaces. *Int J Prosthodont* 2004; **17**: 544–54.
44. Albrektsson T, Zarb G, Worthington P, Eriksson AR. The long-term efficacy of currently used dental implants. A review and proposed criteria of success. *Int J Oral Maxillofac Implants* 1986; **1**: 11–25.
45. Roos-Janasaker J, Sennerby L, Lekholm U, *et al.* A qualitative and quantitative method for evaluating implant suc-

cess: a 5-year retrospective analysis of the Brånemark implant. *Int J Oral Maxillofac Implants* 1997; **12**: 804–14.
46. American Dental Association. *Principles of ethics and code of professional conduct, with official advisory opinions revised to January 2005*. Chicago, IL: ADA, 2005.
47. Quirynen M, Van Assche N, Botticelli D, Berglundh T. How does the timing of implant placement to extraction affect outcome? *Int J Oral Maxillofac Implants* 2007; **22** (Suppl): 203–23.
48. Ardekiar L, Oved-Peleg E, Mactei EE, Peled M. The clinical significance of sinus membrane perforation during augmentation of the maxillary sinus. *J Oral Maxillofac Surg* 2006; **64**: 277–82.
49. Schwartz-Arad D, Gerzberar Dolcu E. The prevalence of surgical complications of the sinus graft procedure and their impact on implant survival. *J Periodontol* 2004; **75**: 511–16.
50. Khoury F. Augmentation of the sinus floor with mandibular bone block and simultaneous implantation: a 6-year clinical investigation. *Int J Oral Maxillofac Implants* 1998; **14**: 557–64.
51. Proussaefs P, Lozada J, Kim J, Rohrer MD. Repair of the perforated sinus membrane with a resorbable collagen membrane: a human study. *Int J Oral Maxillafac Implants* 2004; **19**: 413–20.
52. Byrne R. *The 2,548 best things anybody ever said*, Nos 1850, 1851, 1st Fireside edn. New York: Fireside, 2003.
53. Pecora GE, Cecarelli R, Bonelli M, Alexander H, Ricci JL. Clinical evaluation of laser microtexturing for soft tissue and bone attachment to dental implants. *Implant Dentistry* 2009; **18**: 57–61.

Chapter 2

Implant complications associated with systemic disorders and medications

Louis F. Rose DDS, MD *and Brian L. Mealey* DDS, MS

Introduction

Although dental implants have been a successful option for replacement of lost dentition for nearly five decades, their use in the medical and dental treatment plan is still in its youth. Literature on the medical implications of dental implants is surprisingly sparse, with a need for organization. This chapter is an attempt to begin the process of documenting the science behind this complex, yet critical topic.

Our understanding of the mechanisms of implant success, complications, and failure unfolds from documented case histories, medical data, and clinical research. Yet, as certain as the scientific facts are, there are contradictions and cases with unexpected outcomes yielding both good and bad results. Some cases exhibit outcomes that surprisingly cross the frontier of success, while others seem to head toward failure before the clinician realizes something is wrong. The later example may begin with a common systemic disorder or medical history, seemingly straightforward from the start, only to become bewildering and strenuous to manage. For these reasons we must be critical in case selection and customize treatment plans according to medical condition while managing all medical aspects with vigor, academic excellence, and due diligence.

With patient selection being the critical factor for implant success or survival, the medical condition, pharmacologic implications, and overall health of the patient cannot be overemphasized. When medical conditions are managed wisely, most patients with diseases discussed in this chapter enjoy far better overall health if they enjoy the comfort and confidence of fixed prostheses rather than the struggle, discomfort, and self-awareness of dentures in an age where esthetics and self-esteem have never been more highly valued. Now more than ever, exceptional care must be exercised to ensure that every implant is placed and restored with the objective of being as successful and as safe as possible for each patient.

Etiology

Myocardial infarction

Any variation in medical condition or difference in systemic health of the dental patient has the potential to affect substantially the outcome of dental implants (1, 2). For example, 15% of patients have cardiovascular disease (CVD), with a history of hypertension occurring in 58% of these patients (3). Surveys also indicate that 25% of the population between 35 and 74 years of age are edentulous and have a heightened need for prosthetic dental care (4–8).

CVD has many forms and includes a variety of conditions such as hypertension, atherosclerosis, vascular stenosis, coronary artery disease, and congestive heart failure (9, 10). CVDs in general directly affect the blood supply to tissues through a variety of mechanisms. This manifestation alone impairs the process of healing and affects the oxygen supply delivered through blood flow (Fig. 2.1) (11). The presence of adequate oxygen increases fibroblast activity, collagen synthesis, capillary growth, and macrophage activity, which in turn prevents wound

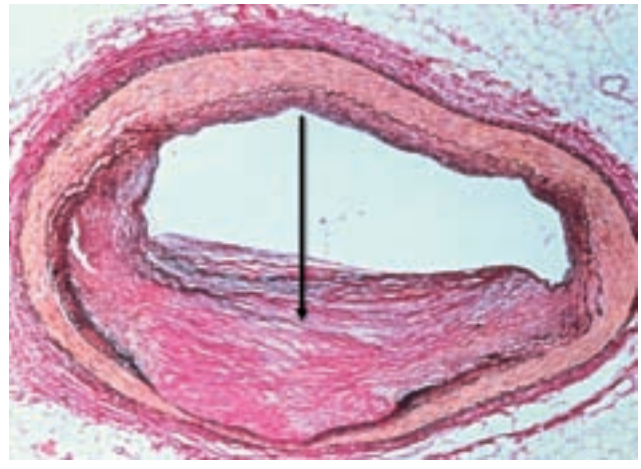


Fig. 2.1 Atherosclerotic coronary artery.

infection (11, 12). These five CVD forms compromise blood flow and reduce oxygen tension and nutrient elements. Thus, we can expect to observe a potential effect on the outcome of the response to osseointegration.

Khadivi *et al.* (13) undertook a retrospective study to survey implant treatment outcome of patients with CVD. There was a total of 246 consecutively treated patients, which comprised a CVD interest group of 39 patients, control subgroups of 98 healthy patients, and 109 patients with a history of other systemic diseases. In that study, the differences in implant failure rates between groups were not found to be significant. Though the sample size was small, the results suggest that CVD may not be a strong risk factor for successful osseointegration.

Ischemic heart disease (coronary artery disease) is most commonly manifested as angina or myocardial infarction (MI). It is the major cause of sudden death in the USA (14–16). MI occurs when the coronary arteries are severely occluded. Thrombus formation and break-up may place the patient at further risk for a cardiac event (Fig. 2.2). MI is associated with discomfort and a severe crushing substernal pain that may radiate to the neck, jaws, or left arm. The greatest risk is ventricular fibrillation and most deaths occur within 12 hours of the event. Elective implant therapy is contraindicated during this period (17).

Given an adequate amount of time, ischemia to the heart generates necrosis and functional deficits. With intervention and a healing period of roughly 6–12 months after preliminary care, patients can re-enter a phase of stability (Fig. 2.3). In the interim period, however, and for 3–6 months after preliminary care, it is prudent to avoid any stress, including stress from surgical procedures that may trigger postischemia complications. About 75% of patients who had MI experience further complications, often within hours or days after the incident (18). Functional recovery occurs within the first month but may continue up to a year following the incident (19).

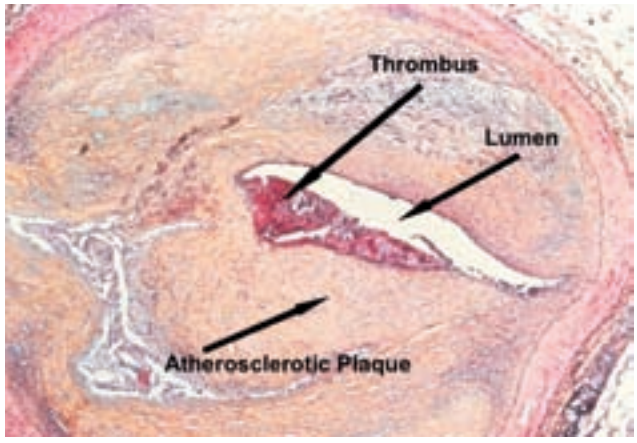


Fig. 2.2 Coronary artery with a significant atherosclerotic plaque and thrombus formation.

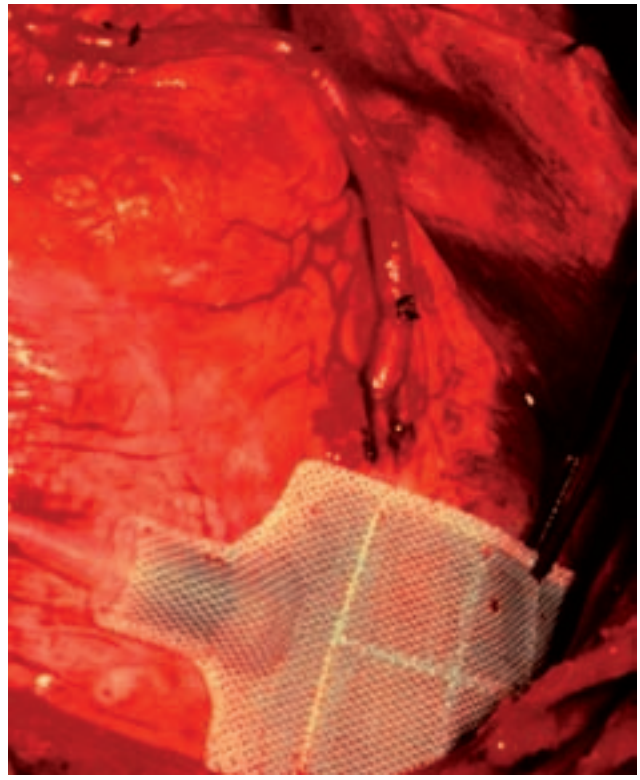


Fig. 2.3 Coronary artery bypass surgery to correct coronary artery disease.

In short, any elective dental surgery including dental implant surgery on patients having active, uncontrolled, systemic diseases may increase risks for further complications and thus jeopardize the patient.

Exercising prudence in patient management, together with thoughtful scheduling of appointments, allows the patient to stabilize medically before undergoing implant surgery and is basic common sense.

Stroke: cerebrovascular accidents

Fatahzadeh and Glick (20) reviewed the underlying pathogenic mechanism for cerebrovascular accidents as the interruption of blood flow and delivery of essential oxygen and glucose to the brain tissue. The brain does not store glycogen and requires 60–70 ml of perfusion per 100 g of tissue per minute for normal function (21). A drop in the blood flow to 25 ml/100 g/minute leads to neuronal ischemia, energy failure, and neurologic symptoms, followed by irreversible tissue damage within minutes should ischemia continue (21–23).

Four neurologic phenomena have been defined for stroke based on their duration: transient ischemic attack (TIAs), reversible ischemic neurologic defect (RIND), stroke in evolution, and completed stroke. A TIA is a sudden, short-lasting, focal neurologic deficit or "mini" stroke caused by transient and localized brain ischemia (24). These neurologic deficits are reversible within days.

RIND refers to a neurologic impairment that is reversible but recovery from which will exceed 24 hours (25). A stroke in evolution is defined as stroke-associated symptoms that progressively worsen over time (24, 25). In contrast, neurologic signs and symptoms that have been stable for more than 24 hours define a completed stroke (24).

Strokes are subclassified into ischemic and hemorrhagic types, based on the underlying pathogenesis (24). Eighty-five percent of strokes are ischemic in nature and involve the occlusion of a cerebral vessel with subsequent brain ischemia and infarction distal to the site of obstruction, which may be caused by either atherosclerotic thrombi or distant emboli (21, 24, 26).

Embolic strokes are classified into arterial, cardioembolic, and cryptogenic subtypes, depending on the site of embolic origin (24). Common sources of cerebral embolism include atherothrombi in the carotid bifurcation of the aortic arch, cardiac disease, and spontaneous thrombosis in hypercoagulable conditions (24, 26). Multiple septic cerebral emboli may also arise from valvular vegetations in bacterial endocarditis (24, 26). Diagnosing the exact source of embolism may be challenging, but this information is critical for reduction of stroke-related deaths (24). Cryptogenic strokes refer to cerebrovascular events in which the source of occlusive emboli remains unknown (Fig. 2.4).

Differentiation of ischemic stroke subtypes is not clinically possible, although certain features may help in diagnosis (21). In general, the neurologic symptoms of thrombotic stroke develop slowly, whereas sudden, multifocal, and maximal neurologic deficits at the onset often indicate an embolic stroke (24, 26). In addition, early seizures and hemorrhagic transformation are more frequent with embolic events.

Three main types of ischemic stroke syndromes have been described. A lacunar stroke results from the obstruction of the small penetrating arterioles that feed the white matter structures and the thalamus (21, 24). Symptoms of small-level stroke are often transient, sparing high-level brain functions (21). Predisposing factors for lacunar strokes include aging and uncontrolled hypertension (24). In contrast, large-vessel stroke is characterized by extensive cerebral infarction and results from thrombotic occlusion of a major intracranial vessel (21). Frequently, high-level brain functions are affected and prognosis is poor (21). Brainstem stroke, the third ischemic stroke syndrome, may result from the occlusion of either small or large cerebral vessels and has a variable clinical presentation (21).

Fifteen percent of all strokes are hemorrhagic in nature (21, 24). Hemorrhagic brain infarction may result either from displacement of cerebral tissues or from toxic effects of extravasated blood (24, 27). Whereas two-thirds of hemorrhagic strokes are caused by intracerebral bleeding, the remaining one-third may be attributed to aneurysmal rupture and subarachnoid hemorrhage. Predisposing risk factors for intracranial hemorrhage include hypertensive encephalopathy, advanced age, hematologic disorders, head injury, strenuous exercise, and abuse of alcohol or illicit drugs (24).

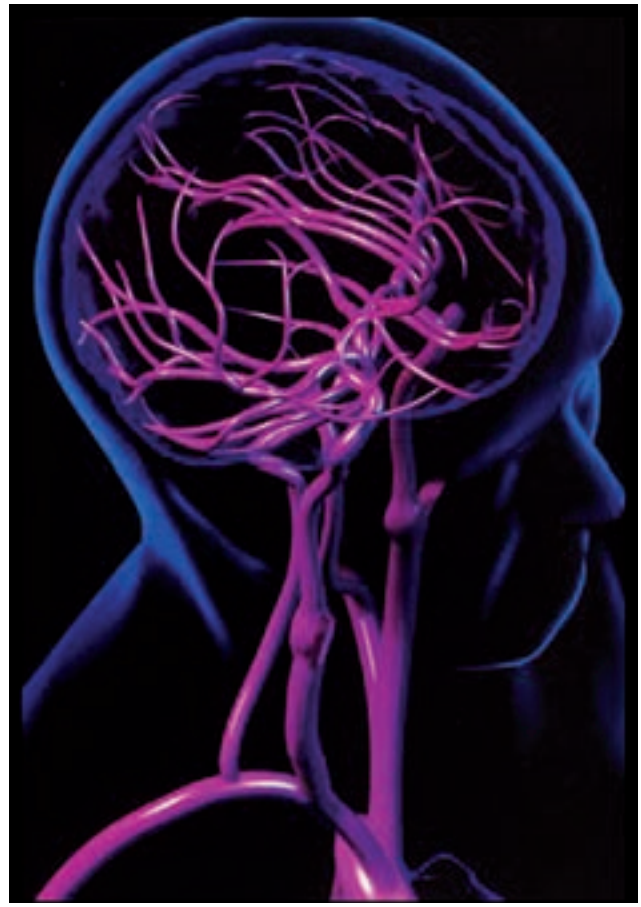


Fig. 2.4 Diagram demonstrating the common sources of a cerebral embolism.

Irrespective of the etiology, brain edema is the first in the poststroke cascade of events (22). The site and duration of occlusion or hemorrhage, presence or absence of collateral circulation, blood pressure, and body temperature are factors that affect the final dimension of brain infarction (24, 27). Clinical manifestations of stroke vary depending on the site and size of the brain lesion (24, 28, 29). Signs and symptoms of stroke are numerous and may include variable sensorimotor dysfunctions such as hemiplegia, hemiparesis, hypoesthesia, compromised eye movements, visual defects, deafness, and language problems, as well as memory disturbance, headache, altered mental status, dizziness, nausea, and vomiting (24, 28, 29). Of these, progressive neurologic impairment, early changes in mental status, abrupt headaches, seizures, and vomiting are more common, and focal neurologic deficits typical of ischemia are less frequent, with hemorrhagic strokes.

The oral manifestations of stroke include loss of sensation of oral tissue and unilateral paralysis of orofacial structures (24, 30, 31). Impaired movement of oral structures may manifest as an inability to manage oral secretions, maintain a protective gag reflex, articulate speech, expectorate, or reproduce a jaw posture necessary for a functional occlusion (32). More than 50% of stroke patients suffer from dysphagia, often having more difficulties managing liquids than solids (32, 33).

Dysphagia-related changes in mastication and dietary habits can potentially lead to poor nutrition, weight loss, and subsequent problems such as poor fit of oral appliances (32, 34, 35). Oral sensorimotor impairment may result in pocketing of food and neglect or oral hygiene on the affected side, both of which predispose patients to caries, periodontal disease, and halitosis (32, 36).

Poststroke depression and lack of motivation often result in the failure of patients to keep their appointments, appreciate treatment objectives, or comply with recommendations.

In summary, CVD and stroke do not directly impact on the success or failure of dental implants. The complications we need to concern ourselves with are directly related to management of these medically complex patients. We need to be vigilant with monitoring blood pressure, patient stress, and interactions of medications. Coumadin (warfarin), aspirin, plavix, and other anticoagulant or thrombolytic drugs need to be respected (Fig. 2.5). Keep appointments short, efficient, personable, and relaxed. Consider using nitrous oxide analgesia or oral anxiolytics as appropriate to make the patient feel at ease. Monitor vital signs and be sure to have profound anesthesia for additional patient comfort. It is always wise to review emergency procedures with your staff well in advance and be mindful of head position and airway freedom on a stroke patient to prevent aspiration of objects or saliva.

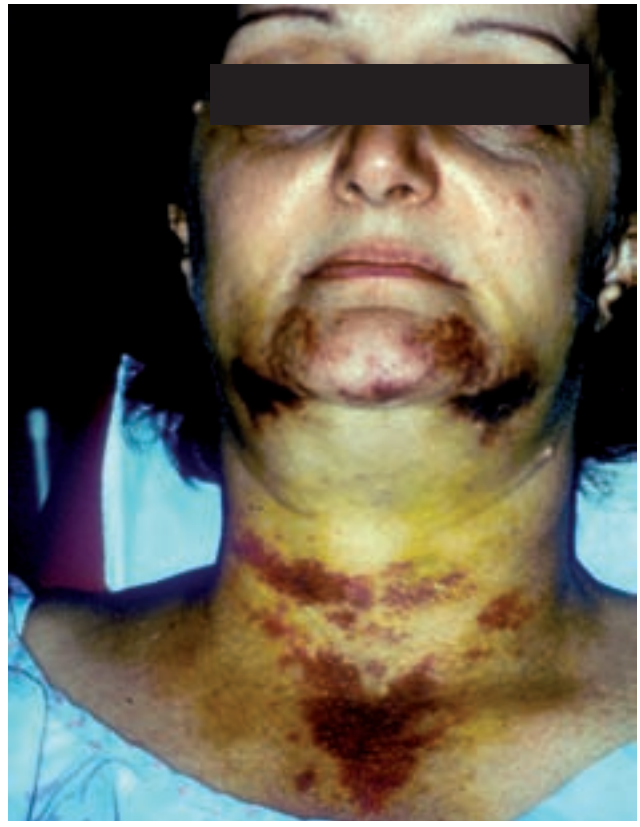


Fig. 2.5 Surgical complication in a patient taking Coumadin.

Valvular prosthesis placement

Valvular heart disease occurs when the heart's valves do not work the way they should. Valve disease can be congenital or acquired and often the cause is unknown (37). According to Rees and Mealey (38), the most important goal of dental and implant therapy in patients with valvular heart disease is the need to prevent infective endocarditis. Dental procedures often cause a transient bacteremia that rarely lasts longer than 15 minutes (39), but the bacteria may lodge on abnormal or damaged cardiac tissue, especially valves, which may result in endocarditis (Fig. 2.6a, b). The percentage of patients with endocarditis who have had recent dental treatment varies widely in the literature, from 3 to 40 percent (39–42).

Once again, valvular heart disease does not directly affect implant outcome; however, the heightened risk of infection needs to be recognized. If the implant becomes infected and does not quickly respond to antibiotics, do not postpone appropriate action. Without delay, remove the implant and proceed accordingly. Again, this is preventive patient management. Above all, the primary focus is to prevent bacteremia and to be mindful of changes in premedication protocols. Consider chlorhexidine mouthrinses before dental procedures as a further precaution.

Osteoporosis

Osteoporosis is a skeletal condition characterized by decreased mineral density (mass/volume unit) of normally mineralized bone (43) (Fig. 2.7). The concern that osteoporosis is a risk factor for dental implants is grounded in the assumption that the bones of the mandible and maxilla are similarly affected to other bones in the body by impaired bone metabolism (44). However, since a potential relationship between osteoporosis and decreased oral bone mass or density is controversial it is not easy to assess whether bone quantity and quality in the mandible and maxilla parallel those in the rest of the skeleton (44, 45).

Also of concern is the assumption that impaired bone metabolism as it occurs in osteoporosis may affect osseointegration of implants (44). However, the process of

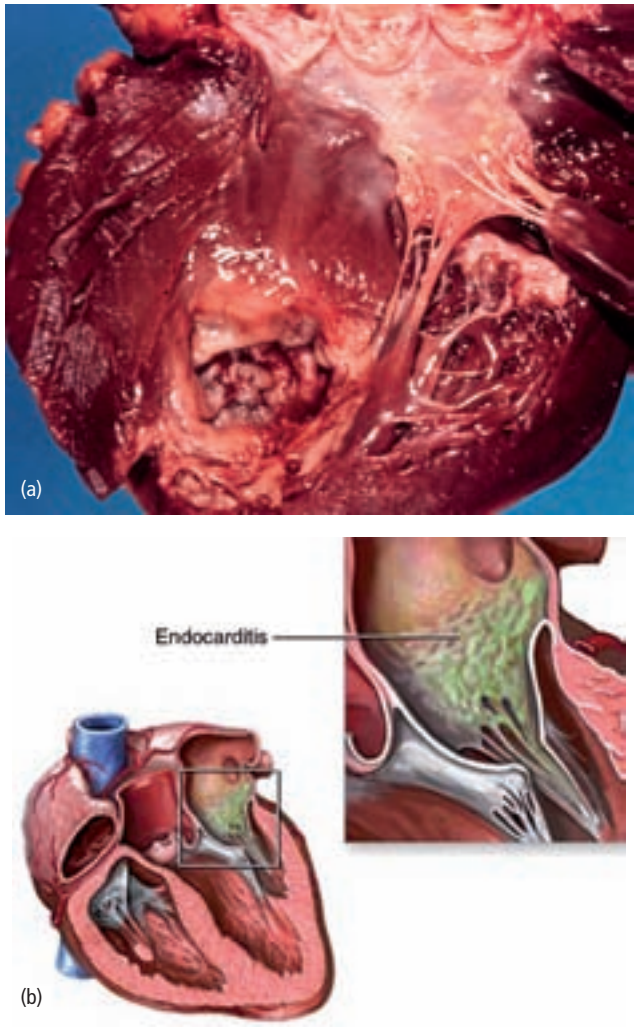


Fig. 2.6 (a) Valvular heart disease in a patient with a history of infective endocarditis; (b) diagram demonstrating infective endocarditis affecting the mitral valve.

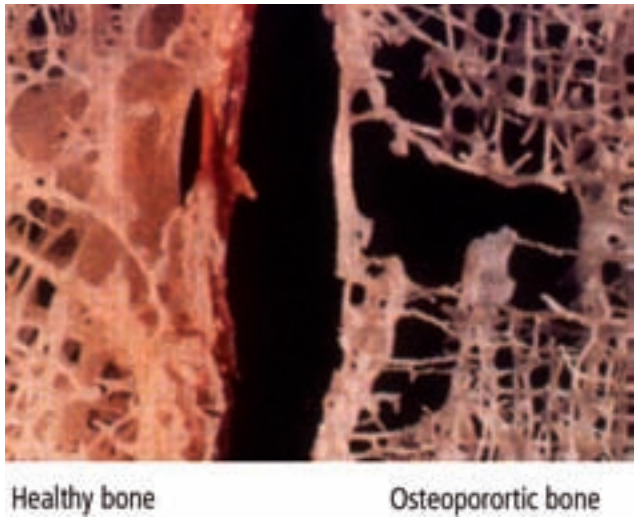


Fig. 2.7 Differences between normal bone and osteoporotic bone.

bone remodeling is a non-uniform process. Bone remodeling differs from one bone to another, between cortical and trabecular bone and from one trabecular bone site to another (45). Trabecular bone is much more affected by metabolic changes in the skeleton and is lost at an annual rate of 0.7% in males and 1.2% in premenopausal females (46). After menopause the decrease in trabecular bone density exceeds that of cortical bone (47). Because of this decrease, bone in the maxilla, which consists mainly of trabecular bone, is more susceptible to rapid and severe atrophy than the mandible, which consists primarily of cortical bone (48). Osteoporotic fractures often heal readily. This suggests that the repair process in osteoporotic patients remains satisfactory (49), indicating that bone remodeling processes after implant placement in osteoporotic patients may not differ fundamentally from those seen in healthy patients (50).

Paget's disease

Osteitis deformans or Paget's disease of bone (PDB) is a chronic disorder of the adult skeleton in which localized areas of bone become hyperactive, resulting in replacement of the normal bony matrix with a highly vascular, softened, enlarged bone. PDB is a localized bone disease that may have widespread distribution, as opposed to a generalized disease such as hyperthyroidism (51).

Under normal physiologic conditions, the skeleton is remodeled to maintain its structural integrity. When the rate of bone turnover is increased, as in PDB, the new bone is formed with less structural order and appears on histologic examination as a disorganized mosaic of woven and lamellar bone (52). Although bone production is disorganized and there is very rapid deposition of new bone in PDB, the primary cellular abnormality in patients with PDB resides in the osteoclasts. The osteoclasts appear to be normal but have increased activity in response to the markedly increased bone resorption (53). The number of osteoclasts in pagetic bone can be increased by up to ten-fold compared with normal bone. The osteoclasts of pagetic bone are also much larger than normal and may contain as many as 100 nuclei in a single cell, compared with three to ten nuclei in a normal osteoclast (54).

The epidemiology of PDB shows a slight male predominance (male:female ratio of 3:2). It is believed to affect 2–3% of the population over the age of 50 years (55). The disease demonstrates increasing prevalence with age (56, 57). The etiology of PDB is unclear. When first described by Paget, it was thought to be inflammatory and to have an infectious origin (58). Current theories have focused on genetic and viral factors. The genetic theories are supported by epidemiologic studies (59, 60); viral theories stem from ultrasonic studies demonstrating nuclear and cytoplasmic inclusions (61, 62). More

recent studies demonstrate that the inclusions resemble paramyxoviruses (63, 64).

PDB is asymptomatic and without clinical findings in approximately 80–90% of those with the condition (65, 66). Among those with symptoms, the major complaint is bone pain; signs of fracture and bone deformation are also noted (67). The jaws are affected in approximately 15% of cases. Common dental complications include malocclusion, tooth mobility, root resorption, hypercementosis, excessive bleeding on extraction, osteomyelitis, and poorly fitting dentures (68). Incidence is more frequent in the maxilla, by a 2:1 ratio.

The diagnosis of PDB is established through clinical and radiographic findings together with biochemical analysis (69). Serum alkaline phosphatase is a biochemical marker of bone formation and in PDB is an accurate indicator of bone turnover and disease activity (52). The radiographic appearance of PDB depends on the stage of the disease. The resorptive phase is characterized by radiolucent lesions (ground glass appearance) and the appositional phase by irregular radiopacity (cottonwool appearance) (69). The agents of choice for treating PDB are the bisphosphonates (70).

The development of osseointegrated dental implant treatment has enabled the dentist to establish greater retention, stability, and support for dental prostheses. Improvements in bite force and chewing efficiency have been demonstrated with the use of implants (71, 72).

Complications for patients with Paget's disease and dental implants mirror the complications indicated for bisphosphonate drug side-effects. Refer to the section on bisphosphonate considerations for further details. Unlike patients with other systemic diseases that do not directly affect implant success, PDB patients have compromised bone density and may be contraindicated for dental implant surgery.

However, the clinician cannot assume from the dental literature that PDB patients need to be denied implants as a viable option in their dental treatment plan. With intelligent management of the PDB patient, it is possible for them to enjoy the benefits of fixed prostheses. Professional consultation with the patient's physician may provide the guidance needed to incorporate short-term bisphosphonate cotherapy, in order to strengthen bone and increase density before implant surgery and ensure maximum success.

Psychiatric disorders

The advice and information in the dental literature regarding dental implant treatment for patients with psychiatric disorders are sparse and contradictory (73, 74). When considering contraindications to implant treatment, psychiatric disorders sometimes have been described in terms of being severe or mild, which is to some extent unhelpful. Psychiatric illness encompasses a wide spectrum of heterogeneous disorders and with appropriate care many psychiatric disorders have a favorable prognosis.

Several psychiatric disorders such as anxiety and mood disorders are extremely common and, therefore, it is inevitable that dentists will see partially dentate or edentulous patients with these disorders who need replacement of missing teeth. Dentists, however, are generally ill informed about the nature of psychiatric disorders (75).

Common-sense approaches to psychiatric disorders must be first and foremost in the mind of dental clinicians, with or without implants in the proposed treatment plan. While psychiatric disorders are not directly linked to an increased risk for implant complications or failure, patient expectations, understanding of treatment and comprehension related to informed consent can be directly linked to successful management of dental implants in the long term.

Alzheimer's disease

Alzheimer's disease is the most common form of dementia. It accounts for 60% of cases of people with loss of cognitive function (76). It is a cerebral degenerative disease of unknown cause that is characterized by memory loss with relatively normal emotional effect (77, 78). The onset of Alzheimer's disease is usually imprecisely dated. The disease has a mean age of onset of 53 years, and is thought to represent an accelerated form of dementia with noticeable inability to initiate spontaneous movement and gradual impairment of intellect and memory (77).

The clinical course of the disease will vary from patient to patient. The first stage is characterized by memory loss, spatial or temporal disorientation, flat effect, lack of spontaneity, and errors in judgment. This stage is thought to last from 2 to 4 years (79–81). People in this stage prefer familiar people, places and things, and are easily upset. Less attention will be paid to appearance and hygiene (78).

The second state is characterized by more rapid and focal losses of cognitive function and partial or total intermittent speech loss. The ability to carry out purposeful movement is lost (apraxia), rendering the person partially or totally unable to perform the activities of daily living (81).

During the third phase the patient becomes profoundly apathetic, disoriented, bed- or chair-ridden, and incontinent. Seizures are common. Patients tend to touch and grasp objects within range. This often results in bringing an object to the mouth to suck on it (79, 81).

Structure, stimulation, and patience are three essential elements in the care of the patient with dementia (82). The six basic activities of daily living (ADL activities), i.e.

bathing, dressing, toileting, transfer, continence, and feeding, as described by Katz *et al.* (83), are learned behaviors. As cognitive function decreases, these behaviors are lost. The caregiver will have to perform many of the ADL tasks for the patient, including dental care.

Visiting the dentist may be complicated for both the patient with Alzheimer's disease and the caregiver (76). The goal of dental care is to prevent loss of oral health function despite the loss of cognitive function. Aggressive prevention of dental problems is critical to the success of the patient's oral health.

When considering dental implants for the patient with Alzheimer's disease it is wise to thoroughly review prescribed medications along with evaluating caregiver commitment and responsibility. Postsurgical oral hygiene, management of drug-induced xerostomia, and regular preventive maintenance are critical for the long-term success of the patient with Alzheimer's. For these patients, all postsurgical homecare, attendance at appointments, and daily oral hygiene are juxtaposed with third party assistance at home. While there is no reason to deny Alzheimer's patients access to dental implants, a responsible patient agent needs to be included in the treatment plan and management strategy.

Parkinson's disease

Parkinson's disease (PD) is a chronically progressive neurologic disorder caused by neurodegeneration (predominantly of the substantia nigra) and leading to an insufficiency of dopaminergic neurotransmitters (84–86). PD affects predominantly older adults and in the USA the disease prevalence is estimated at 400 000–600 000 patients with projected figures of 1–3 million by the year 2040 (86). Three cardinal symptoms characterize PD and cause disability in patients: rigidity, tremor, and bradykinesia. The rigidity is caused by an increase in muscle tone. The muscles are stiff, and movement is jerky and slow. Tremor is a shaking at rest which is observed at a frequency of 3–5 Hz. Voluntary movements are slowed and their initiation is difficult or impossible.

Hypokinesis also affects the orofacial–pharyngeal muscles, leading to problems with speaking and especially with chewing and swallowing (dysphagia). The inevitable reduction in food and fluid intake contributes to the neurologic deterioration. In addition, PD patients experience numerous gastrointestinal symptoms, such as nausea, anorexia, abdominal bloating, heartburn, dysphagia, and constipation (87, 88). In view of the digestive problems associated with the disease, the optimal oropharyngeal preprocessing of food is particularly important.

PD patients have great difficulties in adjusting to the use of complete dentures. The same considerations may apply for the patient with PD as for the patient with Alzheimer's disease. Unlike patients with Alzheimer's though, the patient with PD may not necessarily be an older adult. Advanced stages of PD may require management of certain forms of dementia, but many people with PD are fully functioning, productively employed individuals having needs similar to you and me. While the patient with PD struggles with the sequelae of their disease, the overriding symptom, aside from tremor and muscle rigidity, is that PD patients are slower in accomplishing most common tasks and are seriously stressed if someone is not patient with their inability to move with normal speed. PD patients are particularly self-conscious of this disability and will appreciate others who can respect their inability to move more quickly. With this in mind, the treating clinician should be compassionate in scheduling their appointments and not rush them while they are in the chair. Increasing emotional stress in this manner usually exacerbates outward symptoms of tremor, making it far more difficult to complete the dental work planned for that day.

Helping PD patients with fine motor skills related to oral hygiene around dental implants, suggesting oral hygiene supplies designed for disabled individuals along with caries-preventive therapeutics are additionally helpful.

Refer to the other sections of this chapter on prevention of complications and treatment recommendations for additional information to maximize successful outcomes for the PD patient with dental implants. In the past, medical treatment for PD was limited. Today, however, Parkinson's patients have new drug therapy options that allow them to live exceptionally productive lives in spite of their movement disorder. Although personal management is an ongoing daily activity, PD patients appreciate being treated equally to non-PD patients in the dental setting and can successfully be considered for dental implants.

Pharmacologic considerations

Corticosteroids

Corticosteroids are a common treatment for various systemic diseases. Their use often leads to suppression of a patient's immune response and makes them more prone to developing bacterial, viral, and fungal infections. These infections can be difficult to treat with conventional therapy and patients taking exogenous steroids are at risk for osteopenia and osteoporosis. The clinician should be aware of this when observing the maxilla and mandible (89–92) (Fig. 2.8a, b).

Bisphosphonates

Bisphosphonates are an established category of drugs that function as bone resorption inhibitors by depressing osteoclast function. The efficacy of these agents in

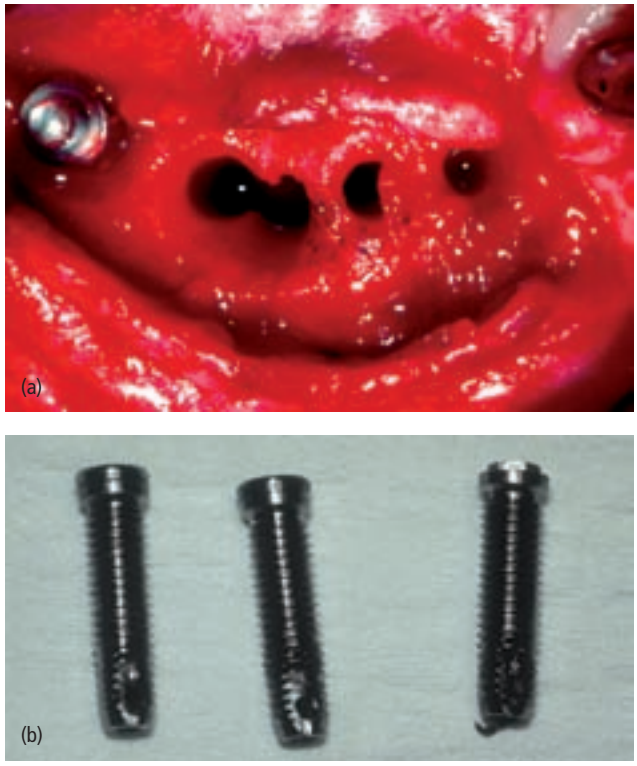


Fig. 2.8 (a, b) Patient on long-term corticosteroids. Failure of the implants was noted 4 months after placement.

treating and preventing the significant skeletal complications associated with these conditions has had a major positive impact for patients and is responsible for their widespread use in medicine. Despite these benefits, osteonecrosis of the jaws has recently emerged as a significant complication in a subset of patients receiving these drugs (93).

A group of intravenous bisphosphonates that contain nitrogen (94) and include pamidronate (Aredia) and zoledronate (Zometa) has been used to inhibit tumor-induced, osteoclast-mediated bone resorption that results in hypercalcemia and osteolytic metastases (95) in malignancies such as breast, prostrate, and lung cancers, multiple myeloma, leukemias, and PDB. In 2003 and 2004, oral and maxillofacial surgeons began to observe and report cases of avascular necrosis (osteonecrosis) of the mandible and/or maxilla correlating to the use of these two intravenous bisphosphonate drugs (94, 96–99).

Oral bisphosphonates are used frequently to treat osteoporosis and osteopenia, and include alendronate (Fosimax), etidronate (Didronel), residronate (Actonel), and tiludronate (Skelid) (100). Patients under treatment with oral bisphosphonate therapy are at a considerably lower risk for osteonecrosis of the jaw than patients treated intravenously (97, 101). However, given the number of patients on oral bisphosphonate therapy, it is likely that at some point, practitioners will encounter patients with osteonecrosis of the jaw (Fig. 2.9). More

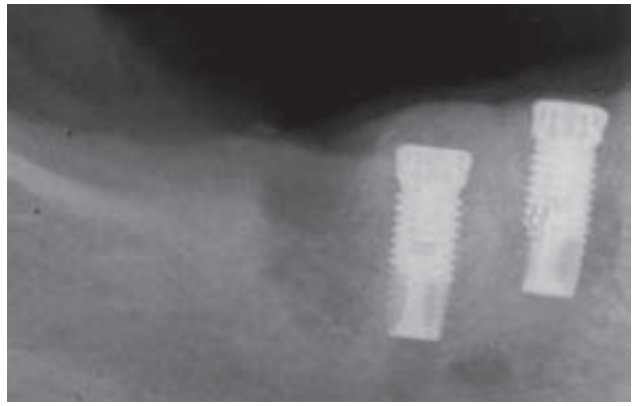


Fig. 2.9 A 64-year-old woman with a history of breast cancer. The patient was treated with chemotherapy and intravenous bisphosphonates, approximately 3 years before placing the implants and extracting the teeth. The radiograph demonstrates osteonecrosis.

studies need to be conducted to determine accurately the incidence of this disease in the population and to assess the risk associated with long-term use of the drugs (102).

A patient is considered to have bisphosphonate-related osteonecrosis of the jaw if they have the following three characteristics:

- current or previous treatment with a bisphosphonate
- exposed, necrotic bone in the maxillofacial region that has persisted for more than 8 weeks
- no history of radiation therapy to the jaws.

Anticoagulants

The three main anticoagulants are coumarin, heparin, and aspirin. They are usually prescribed to treat a number of cardiac or vascular disorders, including atrial fibrillation, ischemic cardiac disease, cardiac valvular disease, prosthetic cardiac valves, post-MI, deep venous thrombosis, pulmonary embolism, cerebrovascular accident, and many others (103–105).

Aspirin use in the USA remains high because of its diverse and beneficial activities. In adults at risk for cardiovascular thrombotic events, low-dose aspirin (81 mg/day) is an excellent preventive agent; however, its antiplatelet properties have contributed to a perceived increased risk for bleeding after dental extractions (106).

Combination aspirin and the adenosine diphosphate PSY (107) receptor antagonist, clopidogrel (Plavix), therapy helps prevent thrombotic complications following a percutaneous coronary stent intervention (108). In contrast, no additional benefit was found for aspirin and clopidogrel compared with aspirin alone to prevent cardiovascular events in patients with atherothrombotic risk factors (109). The combination of aspirin and clopidogrel has been associated with bleeding risk with coronary artery bypass graft surgery (110, 111). However, no

studies have examined whether an increased risk of bleeding exists in the dental setting following extractions compared with more invasive surgical procedures such as coronary artery bypass grafting. Of importance, a recent Science Advisory from the American Heart Association, American College of Cardiology, Society for Cardiovascular Angiography and Interventions, American College of Surgeons, and the American Dental Association recommended continuing aspirin and clopidogrel therapy for minor dental surgical procedures in patients who have coronary artery stents or delaying treatment until the prescribed antiplatelet regimen is completed, and warned of the significant thrombotic risk of discontinuing therapy (112). The risk of acute MI is increased during several weeks after cessation of nonsteroidal anti-inflammatory drug therapy. Overall, the data supported the conclusion that among acute coronary syndrome patients, the discontinuance of daily aspirin use increases the risk for adverse clinical cardiovascular outcomes during the first month after drug withdrawal. A slightly different scenario presents with patients who take higher doses of aspirin (i.e. ≥1 g/day) and require dental extractions. These individuals generally take higher doses of aspirin for its analgesic and/or anti-inflammatory properties, and do not have antithrombotic concerns. Therefore, in patients taking aspirin as an analgesic or anti-inflammatory, aspirin use could be discontinued before dental extractions or surgery, as these patients are not at known risk for thrombosis. However, there are several studies (31, 113, 114) that indicate that aspirin use can be continued without significant concern for dental bleeding when local hemostatic measures are in place.

Antibiotics

The administration of antibiotics in preventing infections following surgical procedures is a common procedure in medicine and dentistry, although such prescription is often empirical (115). The principle of antibiotic prophylaxis before oral surgical procedures, including dental implants, in patients at risk for endocarditis or in those who are severely immunocompromised is well established. Their use in conjunction with implant surgery in healthy patients and its correlation with failure and success rates are still poorly documented in the literature. However, it is widely agreed that total use of antibiotics should be reduced to minimize the emergence of resistant bacterial strains (116).

Age

Patient age in and of itself has not been shown to affect implant complication rates significantly (117). Most clinical studies of implant survival and complications show high success rates, although elderly patients may have more difficulty manipulating removable implant-supported prostheses (118). However, age is definitely associated with the prevalence of systemic conditions that may affect implant success or complication rates. Older patients more commonly suffer from multiple systemic conditions than do younger patients, particularly conditions of a chronic nature such as hypertension, CVD, and osteoporosis, to name a few. For example, the prevalence of type 2 diabetes increases as a given subject population ages (119). Therefore, an older individual is more likely to have diabetes. If diabetes increases the likelihood of implant complications and if the clinician sees a lot of older patients with diabetes, that clinician may diagnose and treat a greater number of implant complications than one who sees mainly younger patients.

Likewise, the effect of risk factors for implant complications may become more obvious as a patient ages simply owing to the cumulative effect of the risk factor over time. For example, smoking may increase the risk of implant complications. A person who has accumulated 50 pack-years of smoking exposure may be more likely to exhibit the negative clinical effects of that accumulated risk exposure than a person who only has a 5-pack-year smoking history. Assuming the two individuals began smoking at the same age, the older individual will accumulate greater risk exposure than will the younger person.

Hormonal changes occurring with age mainly affect women. Of particular relevance to implant complications is the decreased bone mineral density associated with aging in both males and females. Because bone mineral density decreases more rapidly after menopause, older women are more likely to have osteopenia or osteoporosis than are age-matched men. Osteoporosis is discussed later in this chapter.

Another consideration for patient age is the number and variety of medications taken. Overall, the prevalence of polypharmacy increases dramatically with age (120, 121). Medications can certainly result in implant complications, especially as they relate to surgical risk and alterations in wound healing. Many of these will be discussed later in this chapter. For example, older patients with multiple chronic diseases are more likely than younger patients to take medications that increase the risk of intraoperative or postoperative bleeding, postural hypotension, xerostomia and mucosal irritation, gingival enlargement, and immunosuppression. In addition, use of multiple medications increases the risk of drug interactions with medications prescribed by the dentist.

Thus, it is not a patient's age per se that determines risk for implant complications, but rather the increased prevalence of systemic conditions that occur with age, the increased level of risk factor exposure, and the medications that are used in managing such conditions.

Diabetes

Despite its widespread prevalence throughout the world, there is relatively little evidence on diabetes as a direct risk factor for dental implant complications or failure. Diabetes is associated with a wide range of systemic complications including microvascular and macrovascular diseases, altered wound healing, and increased susceptibility to infection (122). These conditions may increase the risk of postsurgical complications following dental implant placement. In addition, diabetes is a major risk factor for periodontal disease. Dental implants are often used to restore function in partially edentulous patients. In these individuals, the clinician must perform a thorough examination of the remaining dentition and must understand those factors that increase the risk for periodontal destruction, such as diabetes. Further progression of existing periodontitis in such patients may alter the functional load on existing implant-supported restorations or may necessitate further implant placement.

Diabetes negatively impacts bone metabolism, with decreased osteoblast differentiation and proliferation, decreased collagen production, and increased osteoblast apoptosis having been demonstrated in hyperglycemic environments (123). Animal models of type 1 diabetes reveal decreased bone-to-implant contact on machined surface and rough surface dental implants placed in diabetic animals compared with non-diabetic animals (124, 125). Trabecular bone volume around implants is also decreased in diabetic animals. Cortical bone remains relatively unaffected. Conversely, animal models of type 2 diabetes have shown no difference in osseointegration or trabecular bone volume around machined surface implants compared with non-diabetic control animals (126). If diabetes does negatively affect osseointegration, it is more likely to impact implants placed in regions with a predominance of cancellous bone, such as the maxilla, than in regions with an abundance of cortical bone such as the anterior mandible. Interestingly, when insulin is used to establish good glycemic control in diabetic animal models, bone-to-implant contact increases markedly compared with animals with uncontrolled diabetes, suggesting that establishing good glycemic control may be an important determinant of osseointegration (127).

A systematic review of the available evidence in 2007 suggested that diabetes might have a small negative impact on implant survival in humans over time (128). However, one of the major findings of the review was the paucity of studies examining this important question. Almost all human studies have been limited to individuals with type 2 diabetes, and few have examined the impact of various levels of glycemic control on implant outcomes (Fig. 2.10a, b).

Studies of implants in the anterior mandible have shown 5-year survival rates of 88–94% in subjects with type 2 diabetes (129, 130). While these studies did not directly compare diabetic and non-diabetic patients, the 88–94% survival rate is somewhat lower than that seen in other studies of non-diabetic subjects. For example, 5-year survival rates of implants placed in the anterior mandible of non-diabetic subjects have ranged from 98% to 100% (131, 132). In a large prospective study of over 2600 implants in various anatomic locations of both non-diabetic and type 2 diabetic patients, implant survival rates at least 3 years after placement were 93% in non-diabetic and 92% in diabetic individuals (133). Conversely, in a smaller retrospective study of 215 implants placed in both type 1 and type 2 diabetic patients the cumulative 6-year survival rate was 85.7% (134).

One of the most important factors in preventing systemic diabetic complications such as retinopathy, nephropathy, and neuropathy is establishing good glycemic control. In general, glycemic control is evaluated clinically through use of the glycosylated hemoglobin assay, or HbA_{1c} (122). This assay allows the determina-

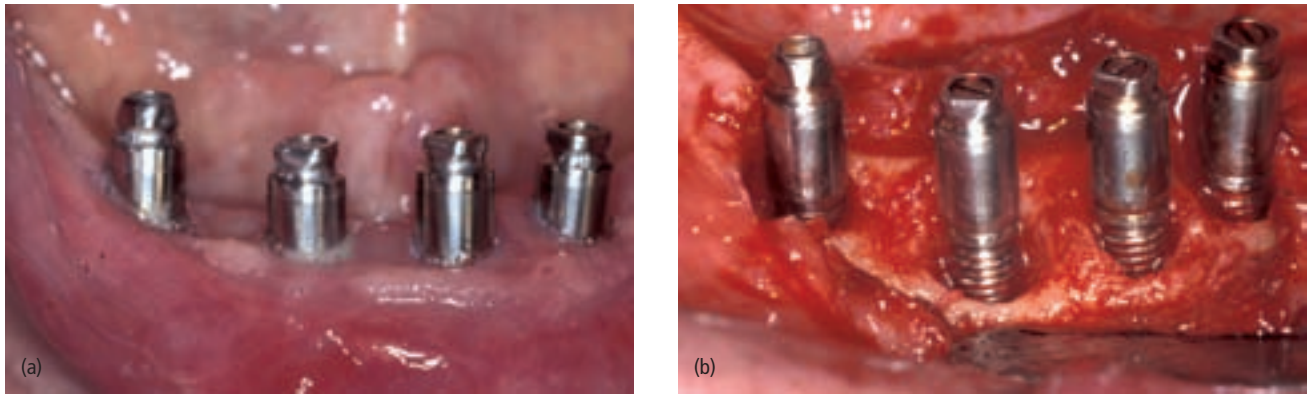


Fig. 2.10 An edentulous patient with type 2 diabetes received four mandibular implants to support a removable complete denture. The patient was only moderately controlled, with HbA_{1c} in the range 8.5–9.3%. (a) Four machined surface implants in anterior mandible; suppuration noted upon probing, with 6–7 mm peri-implant probing depths; (b) flap reflection reveals loss of bone around coronal 3–7 threads of implants. (Courtesy of Dr Chol Chong, United States Air Force.)

tion of the average glucose levels over the 2–3 months preceding the test. A normal HbA_{1c} is less than 6%. The American Diabetes Association (ADA) recommends that most people with diabetes try to control their blood glucose levels well enough to maintain an HbA_{1c} below 7% (135). There is strong evidence that improved glycemic control decreases the risk of long-term diabetic complications (136, 137). However, there is little evidence evaluating the impact of glycemic control on dental implant survival or complications in people with diabetes. Very few implant studies have even examined the level of glycemic control in their diabetic patient populations. A recent study examined the question of how glycemic control affects implant complication rates in type 2 diabetic individuals with HbA_{1c} levels ranging from 4.5% to 13.8% (138). All of the implants successfully integrated and were in function at least 1 year after placement. This small study suggests that implants can be placed successfully in diabetic patients with a range of glycemic control. However, only three subjects had HbA_{1c} levels over 10% and only short-term survival was evaluated, so clinicians should assess these data carefully. In general, poor glycemic control is considered a risk factor for postsurgical infection. Thus, until more data specifically related to dental implant surgery become available, risks associated with implant therapy should be evaluated carefully in diabetic individuals with poor glycemic control, and detailed informed consent should be obtained.

Smoking

There is no question that smoking has numerous deleterious effects on tissues and on the host immunoinflammatory response. Products of tobacco such as nicotine, carbon monoxide, and hydrogen cyanide alter wound healing by decreasing proliferation of fibroblasts and other reparative cells, decreasing tissue perfusion through vasoconstriction, and increasing platelet adhesion (139). Hydrogen cyanide inhibits oxidative metabolism, while carbon monoxide decreases tissue oxygenation by competitive binding to hemoglobin. Smoking upregulates production of certain proinflammatory cytokines such as interleukin-1 and tumor necrosis factor-α, while also adversely affecting humoral immune responses. Smoking has a deleterious effect on secretory immune functions as well, which may adversely impact healing in the maxillary sinus. Smoking decreases osteoblast activity, resulting in diminished bone mineral density and delayed bone healing after surgery.

While these adverse effects of smoking exist and could affect healing following implant placement, the clinical question remains as to the impact of smoking on actual implant survival and the rate of complications. Many studies have examined the impact of smoking on dental implant therapy. Unfortunately, most of these studies do not clearly delineate the degree of smoking exposure such as the number of cigarettes smoked or the duration of smoking (128). Numerous studies report an increased failure rate of implants in smokers compared with non-smokers. In general, the failure rate is reported to be 2–2.5 times higher in smokers (128, 140, 141). In some studies, implants placed in the maxilla are negatively affected by smoking to a greater degree than those placed in the mandible, perhaps owing to the generally greater bone density in the mandible. In addition, the implant surface may have a major impact on the effect of smoking on implant outcomes.

Systematic reviews provide clinicians with the highest level of evidence, and several systematic reviews of data related to smoking and implant therapy have been published in the past few years (128, 142, 143). These studies examining data from thousands of implants confirm that overall, implant failure rates are approximately two-fold higher in smokers compared with non-smokers. For example, in one systematic review the overall survival rate in smokers was 89.7% compared with 93.3% in non-smokers (128). Looked at another way, the overall failure rate was 10.3% in smokers, versus 6.7% in non-smokers.

Several major factors need to be considered in interpreting the results of these smoking studies. First, the impact of smoking may vary with the anatomic location in which implants are placed (Fig. 2.11a–c). A large study of over 2500 implants evaluated at least 3 years after placement demonstrated an implant failure rate of 10.9% for maxillary implants in smokers versus 6.4% for maxillary implants in non-smokers, a difference of 4.5% (141). Conversely, in the mandible the failure rate was 6.9% for smokers and 5.6% for non-smokers, a difference of only 1.3%. This study suggests that the impact of smoking may be greater for maxillary implants than for mandibular implants. This concept was confirmed in a large systematic review that found a statistically significant two-fold increased failure rate in maxillary implants in smokers compared with non-smokers, but no significant difference in mandibular implant failure rates (142). Another systematic review found a 2.0% overall difference in survival rate for smokers versus non-smokers when implants placed in all anatomic locations were evaluated, but the difference in failure rate was 7.4% when only maxillary sites were considered (128).

Another special anatomic consideration for smokers is the impact their habit may have on implants placed in augmented sites such as maxillary sinuses or ridges that have been grafted. Most studies show that implant survival rates in sites that have been previously augmented by bone grafting are similar to sites where implants have been placed in native bone (144–146). However, smoking may be a major factor in altering the outcome in such sites. A large systematic review concluded that smoking has a particularly strong negative effect on the survival

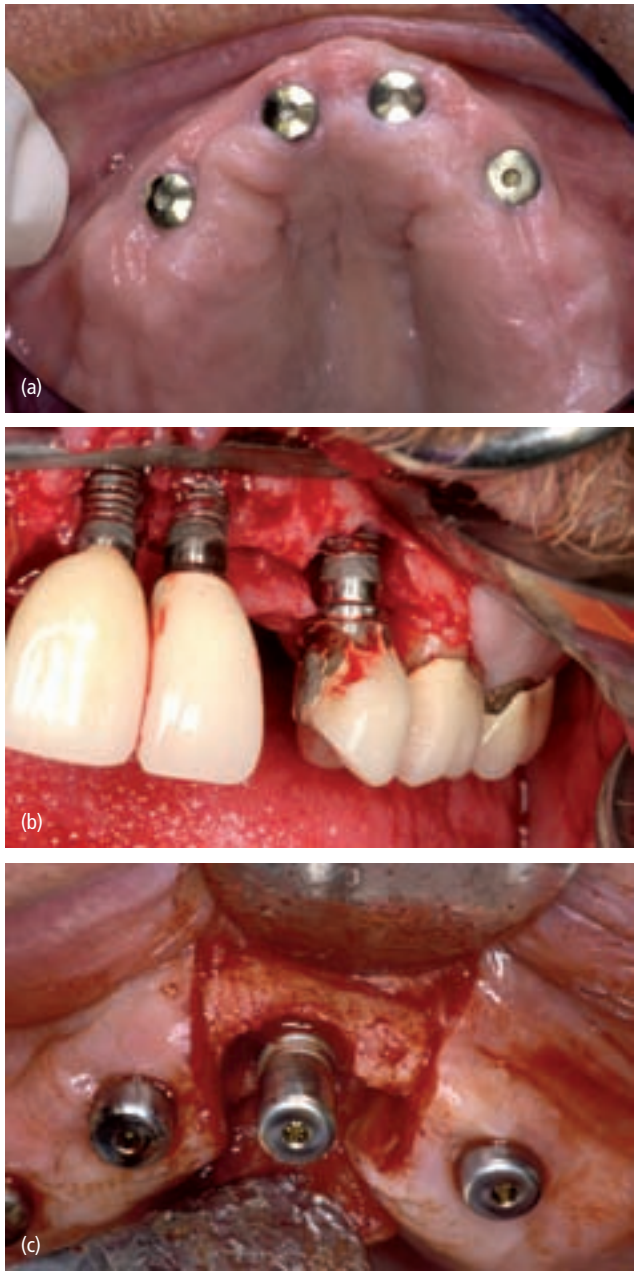


Fig. 2.11 Smoking patient with poor initial integration on maxillary implant: 63-year-old edentulous male with four maxillary implants to support a removable complete denture; the patient had a > 50 pack-year smoking history. (a) Clinical view of maxillary implants 6 months after placement; (b) flap reflection reveals loss of crestal bone around acid-etched microroughened surface of central implant; other implants integrated well, with bone level at top of implant platform; (c) greater extent of bone loss on palatal aspect of implant. (Courtesy of Dr Kenneth Connor, United States Air Force.)

of implants placed in either augmented maxillary sinuses or alveolar ridges. Compared with an overall 2.1-fold increased risk of implant failure in smokers versus non-smokers, when implants were placed in augmented sites in smokers the failure rate was 3.6-fold higher than for implants placed in augmented sites in non-smokers (143). Thus, clinicians should anticipate the possibility of higher failure rates for implants placed in bone-augmented sites in smokers, and should counsel patients accordingly.

Many implant studies include primarily machined surface implants in their data sets because the studies were initiated at a time when machined surface implants were commonly placed. Smoking adversely affects the survival of machined surface implants to a greater degree than rough surface implants. For example, one systematic review showed a statistically significant 2.25-fold increased failure rate in smokers compared with non-smokers when implants of all surface types were evaluated (143). However, when only rough surface implants were evaluated, there was no significant difference in implant survival rates in smokers compared with non-smokers. In another meta-analysis of rough surface dual-acid etched implants, the 3-year cumulative survival rate in smokers was 98.7%, almost exactly the same as the 98.4% survival rate in non-smokers (147). A large study of sand-blasted and acid-etched implants showed initial short-term implant survival rates of 98% for both smokers and non-smokers (148). These results have led many study groups to conclude that rough or microroughened surface characteristics of dental implants may mitigate the adverse effect of smoking on long-term implant outcomes.

Implant failure is not the only concern of clinicians. Implant complications may also occur, including peri-implantitis, soft-tissue inflammation, and loss of alveolar bone. Smoking increases the rate of implant complications in most studies that have examined the question. In a systematic review of 13 studies examining peri-implant bone height over time, 11 of the 13 studies found significantly greater bone loss in smokers compared with non-smokers (143). Again, the negative effect of smoking may be decreased when implants with rough surface characteristics are used. Many of these studies also show an increased rate of peri-implant mucosal inflammation, deeper peri-implant probing depths, bleeding, and suppuration in smokers. Even in studies that have shown no difference in implant survival in smokers versus non-smokers, the rate of soft-tissue complications may be higher in smokers (149). When an absence of such complications is considered as "success", studies show that the success rate of implants in smokers is significantly lower than in non-smokers. For example, a systematic review found a success rate of 91.0% for non-smokers, but only 77.0% for smokers (128).

In addition to the potential negative impact of smoking on implant complication rates, smoking has a clear detrimental effect on the periodontal status of remaining teeth in a dental implant patient. Over 40 years of research supports the concepts that smokers have a poorer periodontal status overall than non-smokers, that smokers are at greater risk of progressive periodontitis,

that smokers are at greater risk of tooth loss, and that smokers do not respond to periodontal therapy as well as non-smokers (139). Thus, the smoking patient is at increased risk of periodontal destruction which may lead to further loss of teeth and alteration in the function of existing implant-supported restorations. In addition, smoking patients who continue to lose teeth may seek further implant therapy, which may then have a greater risk of failure or complications post-treatment.

Immunodeficiency

Immunodeficiency can affect a patient's ability to fight infection and can alter wound healing following trauma or surgery. Infection with the human immunodeficiency virus (HIV) results in major changes in immune function. As the disease progresses, the patient may exhibit acquired immunodeficiency syndrome (AIDS)-related signs and symptoms, among which are oral lesions and infections. While advances in therapy over the past 20 years have radically changed survival rates for people with HIV, the disease remains a leading cause of death worldwide (150). In the USA and other parts of the industrialized world, the use of highly active antiretroviral therapy (HAART) has resulted in decreased mortality rates for HIV patients. HAART has allowed many people with HIV to live long and productive lives relatively free of medical complications. This means that the dentist is likely to see patients with HIV who desire replacement of missing teeth with dental implant-retained or supported restorations.

There is little research on dental implant outcomes in patients with HIV, other than a few case reports and case series which were all published after use of HAART became routine (151–153). These reports all demonstrate that dental implant survival rates are similar in HIV-positive patients using HAART protocols to those seen in healthy patients. In addition, the rate of postoperative complications in these cases was low, similar to what would be expected in a healthy population. It appears that HIV itself is not a major etiologic factor in implant failure or complications. However, each HIV patient must be evaluated individually, as comorbid conditions such as hepatitis or other viral infections, blood dyscrasias, opportunistic infections, and certain forms of cancer may contraindicate implant therapy.

Immune disorders other than HIV can also alter dental implant therapy. Numerous autoimmune diseases exist that affect oral health and surgical risk. For example, Sjögren's syndrome can result in severe xerostomia leading to rampant caries and tooth extraction. Dry mucosal surfaces are easily irritated by tissue-borne prostheses. This may lead a Sjögren's syndrome patient to seek implant-supported restoration. Sjögren's syndrome is not a contraindication to implant therapy, and successful implant treatment has been reported (100). Successful implant therapy has also been reported for patients with other autoimmune diseases such as scleroderma. In patients with autoimmune conditions, the risk of surgical therapy may be increased, and alterations to the surgical treatment plan may be indicated. For example, patients with systemic lupus erythematosus may have multiple organ involvement and may be at increased risk for bacterial endocarditis due to cardiac valvular damage (154). Physician consultation may be warranted for patients with these types of autoimmune diseases.

Systemic steroids are often used in the management of autoimmune disorders to suppress the immune response. Long-term systemic steroids can induce osteoporosis, which should be considered in the risk–benefit assessment for implant therapy (see section on Osteoporosis). Systemic steroids may also cause secondary diabetes, which can also affect implant treatment (see section on Diabetes). Immunosuppressant therapy is commonly used in association with organ transplantation, bone-marrow transplants, and cancer therapy. There is little evidence available to determine the impact of intentional immunosuppression on implant survival, failure, or complication rates. The evidence specific to cancer therapies will be discussed in the section below.

Cancer therapy

Patients with cancer of the head and neck region are often treated with chemotherapy, radiation therapy, or both. These treatments have major negative effects on host defenses and on hematopoiesis. Clearly, a patient undergoing active chemotherapy or radiation therapy is not a candidate for dental implant placement.

In general, implant-retained restorations or prostheses show lower long-term survival rates in patients receiving resective head and neck cancer therapy than do those in patients without prior cancer treatment (155). However, it is important to distinguish between patients who have received surgical resection, chemotherapy, radiation therapy, or some combination of treatments. Very little research has been done examining the effect of chemotherapy on implant success and survival rates. The data that are available suggest that a history of chemotherapy before implant placement or a history of chemotherapy after successful integration and restoration of implants has no negative effect on implant survival (156, 157).

Radiation treatment has been studied much more extensively than chemotherapy. Radiation therapy has numerous factors that can affect the risk for implant failure or complications (158). The radiation dose is usually not uniform across the various regions of the jaws. Some areas may receive very high doses while adjacent regions receive little, if any, direct radiation. High-dose radiation markedly decreases vascularity of the bone, a process

which continues in the irradiated bone long after treatment. Many patients with oral tumors undergo surgical resection of soft and hard tissues, which can grossly decrease vascularity and can result in limited amounts of remaining bone, often in areas difficult to place dental implants in favorable positions for restoration. Some patients are then reconstructed with bone grafts that may or may not have good vasularization postgrafting. All of these factors can increase the failure and complication rates of dental implants.

Systematic reviews of the evidence suggest that implant survival rates are lower in alveolar bone that has been previously irradiated than in non-irradiated bone (159). Implant failure is relatively low when radiation doses are below 45 Gy. Once above the 45 Gy level, however, the failure rate does not appear to increase with increasing radiation dose. A systematic review determined a failure rate of 5.4% at radiation doses of 46–55 Gy, a 5.2% failure rate at 56–66 Gy, and a 5.1% failure rate at doses above 61 Gy (159). In this review, the implant failure rate was higher in the irradiated maxilla (17.4%) than in the irradiated mandible (4.4%). Most implant failures occur during the first 3 years after placement in previously irradiated bone. No significant differences in implant failure rate were found when radiation was received before implant placement versus after successful implant placement and osseointegration. In examining 19 studies of implant placement in irradiated patients, the overall failure rate was 3.2% when radiation followed implant placement compared with 5.4% when radiation preceded implantation (159).

When implants are placed following irradiation, the failure rate may be higher if implants are placed a long time after radiation therapy compared with placement at a shorter time from radiation treatment. In a study of 631 implants in 107 irradiated cancer patients, implant survival decreased significantly when implants were placed longer than 15 years after irradiation (160). The highest survival rates were seen when implants were placed within 8 years of irradiation. When implants were placed more than 15 years after radiation therapy, the long-term survival rate dropped to less than 50%. Overall, the survival rate was approximately 76% in this study, again demonstrating that clinicians and radiation patients should expect lower survival rates than had the patient not received radiation.

Many irradiated patients have also undergone tumor resection and subsequent bone grafting. In a study of 71 patients treated by resection and radiation therapy with 50 Gy of radiation dose, followed by placement of 316 mandibular implants, the implant failure rate after 8 years was 72% when implants were placed in previously irradiated bone, 95% when implants were placed in non-irradiated bone, and only 54% when implants were placed in previously grafted bone (161).

One of the major and potentially devastating oral complications of radiation therapy is osteoradionecrosis (ORN). Hyperbaric oxygen therapy has been widely used to prevent and treat ORN. Hyperbaric oxygen therapy increases tissue vascularity and oxygen tension by promoting angiogenesis. As implants have become more common in irradiated patients, hyperbaric oxygen therapy has been used to attempt to improve implant survival rates and decrease implant complications, one of which is ORN. While some studies have shown improved implant survival rates with hyperbaric oxygen therapy (160), others have not (162). A Cochrane review of this issue revealed a paucity of high-quality studies (163). Unfortunately, only one randomized controlled trial has examined the effect of hyperbaric oxygen on implant survival when compared directly with a control subject group that did not receive hyperbaric oxygen. All implants were placed in the anterior mandible, and five out of 13 patients who received hyperbaric oxygen had at least one implant failure compared with two out of 13 in the non-hyperbaric control group. Overall, there were no significant differences between groups in the number of implant failures. The effect of hyperbaric oxygen therapy on implant outcomes requires more study before a recommendation can be made to include this treatment in clinical protocols.

Prevention

Myocardial infarction

Previous guidelines for elective dental surgery on MI survivors suggested a 6-month waiting period for cardiac stabilization (164). More recent studies (165) suggest that a post-MI patient who has been medically determined to be not at risk of continued ischemia may be allowed to undergo dental surgery as early as 6 weeks after the event if established protocols are followed. These include consultation with a physician, obtaining patient consent, and patient assessment.

Nitrate premedication, administration of oxygen, achievement of profound local anesthesia, stress reduction measures, perioperative pain medication, and patient monitoring of blood pressure and heart rate are all part of these protocols (165). In addition, the use of conscious sedation may be beneficial in maintaining patient comfort and relaxation. Niwa *et al.* (164) and Findler *et al.* (14) report that the key issues are pain control and stress management.

The dental care professional must also be aware of any anticoagulant or thrombolytic therapies administered, and understand that the desire for oral implants does not necessarily justify interruption of a therapeutic international normalized ratio (INR) (19).

Stroke: cerebrovascular accidents

In general, a standard evidence-based protocol for dental management of stroke patients is not available, and current recommendations are based primarily on intuitive extrapolations from the medical literature. Major issues to be considered when treating patients at risk for or after a stroke include screening for risk factors, hemostasis, drug actions and interactions, stress induced by the dental care, empathetic approach by the dental staff, and individualized oral care programs.

Some authors recommend a cautious approach by deferring the elective dental care for the first 6 months following a stroke and in patients experiencing TIAs or RINDs (36).

Therapeutic administration of single or combination antiplatelet agents or subcutaneous low molecular weight heparin is usually not clinically significant, necessitating little modification to the dental protocol (166, 167). However, a preoperative assessment of hemostasis before invasive oral procedures should be undertaken in patients taking oral anticoagulants. The risk of a thromboembolic event caused by the interruption of oral anticoagulants and subtherapeutic INR frequently outweighs the benefits of postoperative hemostasis in a patient undergoing uncomplicated oral surgery (168, 169). Local measures such as atraumatic surgical techniques, pressure, gelfoam, suturing, electrocautery, and topical hemostatic agents are often sufficient for control of excess bleeding (103) and usually negate the need for reduction in dose or interruption of anticoagulation when the INR is below 3.5. For complicated oral surgery, however, consultation with the physician is recommended if the INR is greater than 3.5 or if the patient is on intravenous heparin.

Aspirin and other non-steroidal anti-inflammatory agents may increase postoperative bleeding in patients taking oral anticoagulants (Fig. 2.12). Acetaminophen-containing products, cyclooxygenase-2 specific inhibitors, opioids, and related analgesics may be considered as suitable substitutes (170, 171). Potential interactions between prescribed dental medications and oral anticoagulants are also a concern. For instance, metronidazole and erythromycin as well as tetracycline may increase INR by inhibiting metabolism of Coumadin as well as reducing prothrombin activity, respectively (172–175). These interactions require the clinician to avoid concurrent administration of metronidazole or erythromycin with oral anticoagulants and closely monitor INR when the patient is taking both Coumadin and tetracycline (172).

Alleviation of stress before and during dental treatment, especially invasive surgical procedures such as dental implants, may be accomplished by nitrous oxide inhalation sedation and/or premedication with oral anxiolytics as well as profound anesthesia and short dental appointments (176). Preoperative and intraoperative vital signs should also be monitored and recorded. In addition, the use of rubber dam, effective oral evacuation, and facilitative head positioning help alleviate a patient's fear of choking and reduce the risk of aspiration (32). Though many stroke victims are adequately managed in an outpatient environment, some may require airway protection through intubation in the operating room.

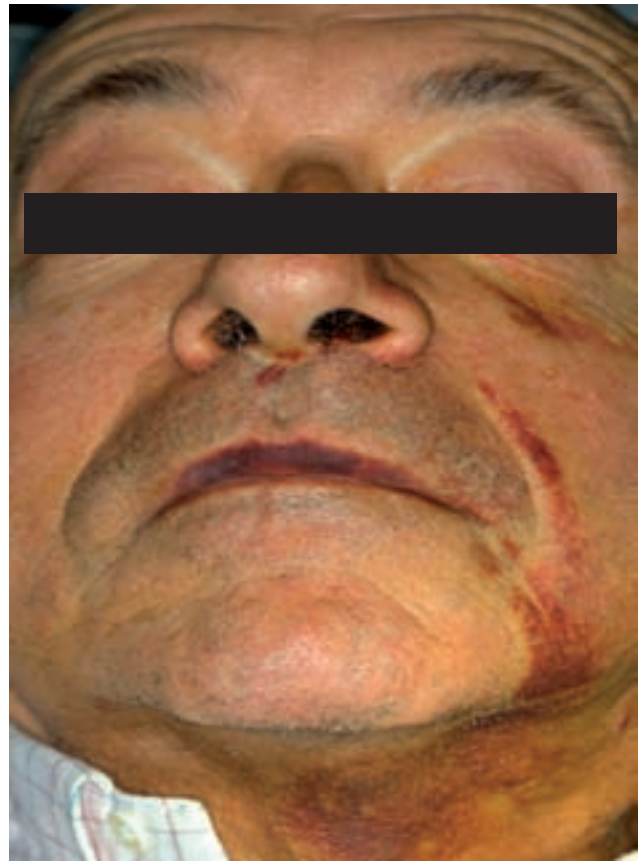


Fig. 2.12 Complications associated with excessive bleeding in a patient taking aspirin and antiplatelet medication.

Valvular prosthesis placement

Most cases of infective endocarditis involving oral microorganisms probably are caused not by dental treatment, but by dental disease, mastication, and oral hygiene procedures (39). Guntheroth (41) found that while dental extractions induced bacteremia in 40% of patients, normal mastication and toothbrushing induced bacteremias in 38% and 25% of patients, respectively (41). He concluded that the exposure time to bacteremias during a 1-month period was 1000 times greater from routine chewing and toothbrushing than it was from dental treatment, extraction, or dental implant placement. Therefore, only patients at risk of developing infective

endocarditis should receive prophylactic antibiotics. Except for these conditions, antibiotic prophylaxis is no longer recommended for any other form of congenital heart disease (177).

According to the American Heart Association (177), there is a risk of infective endocarditis and antibiotic prophylaxis is recommended in patients with:

- artificial heart valves
- past history of infective endocarditis
- serious congenital heart conditions such as:
  - unrepaired or incompletely repaired cyanotic congenital diseases including those with palliative shunts, conduits
  - a completely repaired congenital heart defect with prosthetic material or device, whether placed by surgery or by catheter intervention
  - during the first 6 months after the procedure
  - any repaired congenital heart defect with residual defect at the site or adjacent to the site of a prosthetic patch or prosthetic device
- a cardiac transplant which develops a problem in a heart valve.

It would be prudent to consult with a patient's physician before proceeding with dental implant therapy. Since these patients may undergo multiple courses of antibiotic therapy, the risk of establishing resistant strains increases. As prevention, numerous procedures should be accomplished at the same appointment, if possible. It may be practical to allow at least 7 days to elapse between appointments or to select an alternate antibiotic regimen for appointments within this 1-week period (39). As a local adjunct to systemic antibiotic prophylaxis, a chlorhexidine mouthrinse has been recommended before dental procedures.

Osteoporosis

An updated medical history should be obtained before implant surgery. Patients at risk for metabolic bone disease should be assessed carefully, their nutrition evaluated and any systemic issues should be handled first (178). Physiologic doses of vitamin D (from 400 to 800 IU/day) and calcium (1500 mg/day) are recommended during the postoperative period (178). A balanced preoperative and postoperative diet should be followed and patients should attempt to give up smoking, since smoking is an important risk factor for osteoporosis (179) and implant failure (140).

In cases of insufficient bone volume, the implant sites should be augmented before or during implant surgery (180). In addition, the occlusal load should be properly distributed throughout the dentition to avoid overloading the implant, which may contribute to implant loss (Fig. 2.13a, b). The healing period should be extended by 2 months before the placement of the prosthesis: 8 months versus 6 months in the maxilla, and 6 months versus 4 months in the mandible (181, 182).

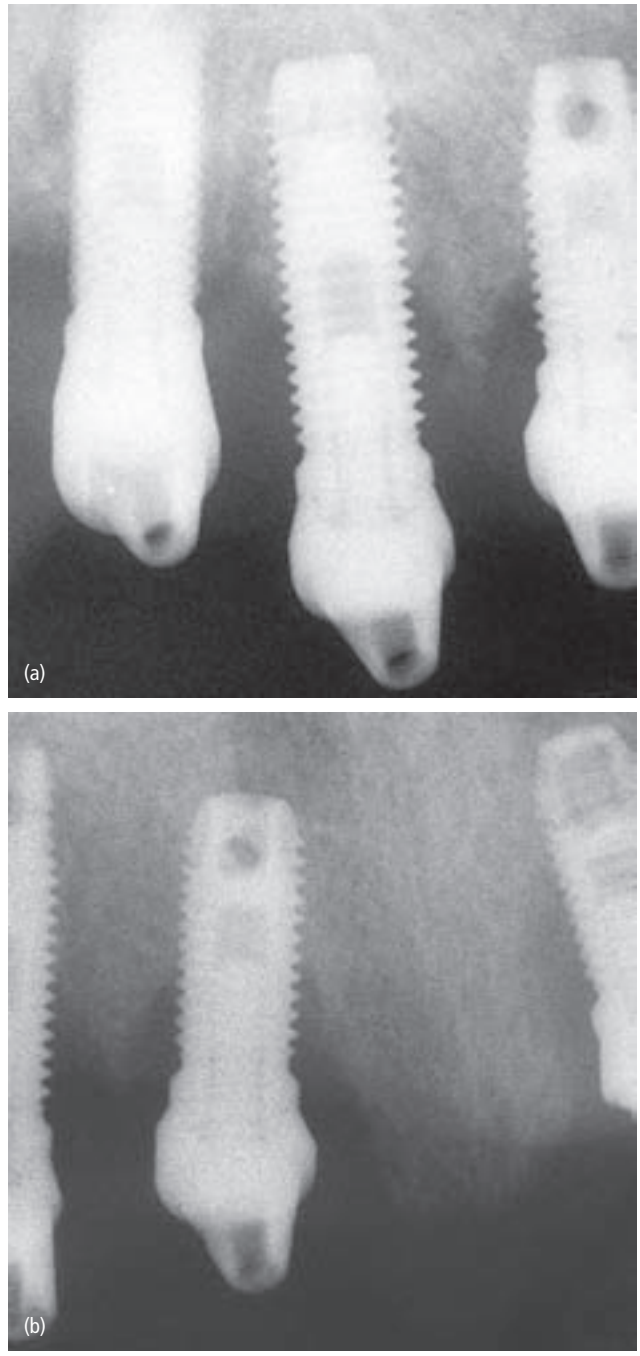


Fig. 2.13 (a, b) Patient with severe osteoporosis 3 months after the provisional restoration was placed.

Implant designs that assure a stable bone implant interface at insertion should be selected to overcome the inability of less dense osteoporotic bone to stabilize the implant. It seems prudent to assure primary fixation of self-tapping threaded implants without cortical countersink procedures (178).

Paget's disease of the bone

Modern dental implants are placed into the bone with the goal of becoming rigidly fixed to the bone in a process of osseointegration (183). When bone density is low, the likelihood of achieving osseointegration diminishes (184). The low bone density associated with PDB may therefore be considered as a relative contraindication to implant placement. No clinical reports are found in a MEDLINE search of the dental literature when using the terms "osseointegration" and "Paget's disease", although Roberts *et al.* (48) describe it as a potential risk factor.

If a definitive positive diagnosis of the disease had been obtained for the proposed implant sites preoperatively, and the patient's serum alkaline phosphatase concentration was at least three to four times higher than normal, limited oral bisphosphonate therapy may have been considered before implant placement. This drug therapy would have been considered to improve the bone quality in the area and to decrease the potential hypervascularity in the proposed sites. Because an oral bisphosphonate would have been considered for a relatively short period of treatment, the risk of inducing osteonecrosis of the jaw would have been minimal. Osteonecrosis of the jaw has been observed in some patients having intravenous oral bisphosphonate therapy for cancer or osteoporosis treatment (97, 185, 186). This treatment would have been given in consultation with the patient's personal physician.

Psychiatric disorders

Nowadays, even patients with severe mental health disorders can respond well to treatment and therefore a psychiatric disorder per se is not a contraindication to provision of implants. However, without a psychiatric opinion, dentists may not be in a position to decide whether a patient should be considered unsuitable for implant treatment and may be unfairly discriminatory. There are clearly some patients for whom implant treatment will be contraindicated. It is essential that patients fully understand the proposed implant treatment, including the requirements for maintenance, and do not have unrealistic expectations. Patients who lack insight or are actively psychotic would therefore not be suitable. If there is any doubt about suitability it is imperative to obtain the opinion of a psychiatrist, though it should be noted that many doctors, including some psychiatrists, are not well informed about the nature of dental implant treatment. The dentist must ensure that the physician understands all the treatment implications from surgery to the need for good oral hygiene and maintenance. Closer liaison of dentists with clinical psychologists and psychiatrists can produce more effective treatment and reduce long-term morbidity (187, 188).

Alzheimer's disease

Complex oral restoration and rehabilitation, which includes dental implant treatment, have a better chance for success in the early stages of Alzheimer's disease. As cognitive function decreases, the patient's ability to adjust to prosthetic appliances diminishes along with his or her ability to cooperate during dental treatment. When oral health function is restored, oral health must be maintained. Aggressive preventive modalities are required to ensure maintenance of oral health. Age, poor oral hygiene, and a carbohydrate-rich diet are known risk factors for oral diseases (76).

The patient with Alzheimer's disease may be exposed to additional risk factors. Medications may result in a dry mouth which increases an individual's risk for caries or periodontal disease, as well as dysfunction of speech, chewing, swallowing, and taste (189) (Fig. 2.14).

The dental evaluation of the patient with Alzheimer's disease begins as usual with a good medical history. The medical history can usually be obtained from the caregiver or the physician. These patients may have various medical conditions in addition to their dementing illness. Of particular concern is the medication history, which complements the medical history and provides an assessment of the level of each systemic illness (76).

Aggressive prevention will avoid the need for extensive restorative treatment at a time when the patient is unable to cooperate (76).

Parkinson's disease

For edentulous PD patients, the use of dental implants to anchor overdenture prostheses would appear to be a desirable service. With one-stage implants (190), the surgical treatment impact can be minimized and, likewise, long-term prosthesis stabilization expected (191).

Muscular equilibrium, which normally stabilizes a prosthesis in static and dynamic conditions, is greatly

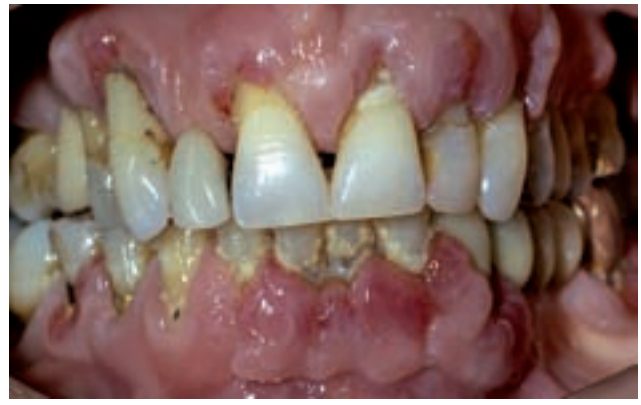


Fig. 2.14 Patient with Alzheimer's disease demonstrating severe periodontal disease, caries, dry mouth, and poor oral hygiene. The potential for implant complications is greater in the late stages of Alzheimer's disease.

reduced in PD patients as a result of their motor system dysfunction (87). The ideal case of stabilization via the synergistic and antagonistic cooperation of the orofacial musculature is limited, making it difficult to ensure the stabilization of the prosthesis, especially in the mandible. As a consequence, PD patients present particular difficulties for treatment with removable prostheses.

When treating edentulous PD patients, implant-supported overdentures may considerably improve the patients' condition, both objectively and subjectively. Improved chewing capacity, a moderate gain in body weight, and an improved glycemic index (GI) score as signs of improved predigestion were observed. Using a non-rigid (resilient) telescopic system for overdenture anchorage, the patients had no problems with the handling and maintenance of the prostheses and the implants. It is suggested that the treatment modality may be beneficial in other patients with motor skill limitations (192).

Pharmacologic considerations

Corticosteroids

Scully *et al.* (193) found no evidence that corticosteroid therapy is a contraindication to endosseous implants, but it is important to consider that systemic corticosteroids can cause suppression of the hypothalamic–pituitary–adrenal axis, and that standard recommendations are that steroid cover is required for operations (193, 194). Although this has been challenged on theoretical grounds in patients on less than 10 mg prednisolone daily (195), and others have shown no significant problems in patients having gingival surgery without corticosteroid cover (196), the Medicines Control Agency still advise cover, noting that patients who encounter stresses such as trauma, surgery, or infection, and who are at risk of adrenal insufficiency, should receive systemic corticosteroid cover during these periods (197). This includes patients who have finished a course of systemic corticosteroids of less than 3 weeks' duration in the week before the stress. Although there is no evidence that corticosteroid therapy is a contraindication to implants, such patients may not be a good risk group (198). Medical advice should be taken first and although the evidence for steroid cover may be questionable, medicolegal and other considerations suggest that one should act on the side of caution and give a steroid cover unless quite confident that collapse is unlikely (193, 194).

Bisphosphonates

A patient considering intravenous bisphosphonate therapy requires a thorough oral examination and must attain dental stability before drug instigation. Elimination of any active infection is vital. If any issue warrants oral surgery, including dental implants, healing must be complete before intravenous bisphosphonate use (199).

Asymptomatic patients receiving intravenous bisphosphonates should maintain good oral hygiene and dental care to prevent dental disease that may require dentoalveolar surgery. Procedures that involve direct osseous injury should be avoided. Placement of dental implants should be avoided in the oncology patient who was exposed to the more potent intravenous medication on a frequent dosing schedule (4–12 times a year) (200).

Surgery is not contraindicated with use of oral bisphosphonates, but the dental provider must exercise caution and the patient must be informed of the potential complications (201). Sound recommendations for patients taking oral bisphosphonates that are based on strong clinical research designs are lacking. It appears that the risk of developing bisphosphonate-related osteonecrosis of the jaw associated with oral bisphosphonates increases when the duration of therapy exceeds 3 years.

The American Association of Oral and Maxillofacial Surgeons (AAOMS) has issued the following recommendations for patients taking oral bisphosphonates (102):

- For less than 3 years with no clinical risk factors:
  - no alteration or delay in the planned surgery is necessary
  - consent for dental implant surgery should be obtained relating to possible future implant failure and possible osteonecrosis of the jaw
  - regular recall schedule.
- For less than 3 years and who also take corticosteroids concomitantly:
  - physician should be contacted
  - discontinuation of the oral bisphosphonate for 3 months before surgery
  - bisphosphonates may be resumed after osseous healing.
- For more than 3 years without any steroid or prednisone use:
  - physician should be contacted
  - discontinuation of the oral bisphosphonate for 3 months before surgery
  - bisphosphonates may be resumed after osseous healing.

Anticoagulants

Concerns exist about intraoperative and postoperative bleeding in patients undergoing anticoagulation therapy and the best management for the situation. Surgery, including dental implant surgery, is the main oral healthcare hazard to the patient with a bleeding tendency. The traditional management entails the interruption of anti-

coagulant therapy for dental surgery to prevent hemorrhage. However, this practice may increase the risk of a potentially life-threatening thromboembolism (202).

The management of oral surgery procedures on patients treated with anticoagulants should be influenced by several factors: extent and urgency of surgery, laboratory values, treating physician's recommendation, available facilities, dentist expertise, and patient's oral, medical, and general condition (202).

Whenever possible, potentially problematic surgical procedures are best carried out in the morning, allowing more time for hemostasis before nightfall, and early in the week to avoid problems at the weekend when staffing may be less intense. Surgery should be performed with 2% lidocaine (lignocaine) with 1:80 000 or 1:100 000 epinephrine (adrenaline) unless the patient is also an active cocaine abuser or a cardiac patient, in which case epinephrine should be avoided (202).

Surgery should be carried out with minimal trauma to both bone and soft tissues. Local measures are important to protect the soft tissues and operation area and minimize the risk of postoperative bleeding (202).

In the case of difficult extractions before implant placement, when mucoperiosteal flaps must be raised, the lingual tissues in the lower molar regions should preferably be left undisturbed because trauma may open up planes into which hemorrhage can tract and endanger the airway. The buccal approach to lower third molar removal is therefore safer (203). Minimal bone should be removed and the teeth should be sectioned for removal where possible (203).

Meticulous curettage of the extraction site is essential to avoid excessive bleeding (103) because when postoperative bleeding occurs, the cause is not necessarily the prolonged INR but may be local infection. In the case of multiple extractions, postoperative bleeding does not occur in all extraction sites; rather, it usually occurs in only one site, often a location associated with severe periodontitis.

According to Scully and Cawson (203), bleeding should be assessed intraoperatively and if there is concern, one should place in the extraction site an absorbable hemostatic agent such as oxidized regenerated cellulose, resorbable gelatin sponge, collagen (synthetic or microcrystalline or porcine), cyanoacrylante, or fibrin glues, which consist mainly of fibrinogen and thrombin and provide rapid hemostasis and tissue sealing and adhesion. Commercial, viral inactivated products are available in Europe, Canada and Japan, but recombinant fibrin products will find more favor. Suturing is desirable to stabilize gum flaps and to prevent postoperative disturbance of wounds when eating. Resorbable sutures are preferred because they retain less plaque. Nonresorbable sutures should be removed at 4–7 days. Gauze pressure (a tranexamic acid soaked gauze helps) should be applied and, after 10 minutes of biting on gauze, hemostasis should be assessed.

To manage patients on warfarin and other oral coumarin anticoagulation therapies it is important that a complete medical history be taken and the dental clinician should be in contact with the patient's physician. It is also prudent for the surgeon to obtain an INR level on the patient before surgery. Dentists have an obligation to their patients to advise continuation of therapeutic levels of anticoagulation, but if the patient and physician insist, then it should be the physician who withdraws the anticoagulant therapy and the dentist who performs the dentistry (168).

The World Health Organization recommends that laboratory values be determined by the INR for reporting prothrombin time (PT) values (Table 2.1). The INR is the PT ratio (patient PT/control PT) that would have been obtained if an international reference thromboplastin reagent had been used (202). With an INR of more than 3.5 and with other risk factors present, the patient should be treated in a hospital (202).

Table 2.1 Oral anticoagulant therapy and oral surgery

HbA_{1c}	Prothrombin time	Thrombotest	INR
Normal level	< 1.3	> 70%	1
Therapeutic range	2–4.5	5–20%	2.5
Levels at which minor oral procedures can be carried out	< 2.5	> 15%	< 3.5

INR: international normalized ratio.

Antibiotics

Assessment of patient risk factors, review of the medical history, including medication allergies, a diagnosis of the anatomic site and its condition, and assessment of the dental procedure being proposed, are critical parts of the process when deciding to prescribe antibiotics for dental implant procedures.

It is recommended that those patients at risk for infective endocarditis and those with artificial hip and/or knee replacements premedicate before dental procedures. The guidelines (39) for oral premedication are as follows:

- Standard prophylaxis: amoxicillin 2.0 g, 1 hour before the procedure
- Allergic to penicillin: clindamycin 600 mg, 1 hour before procedure or cephalexin 2.0 g or azithromycin 500 mg or clarithromycin 500 mg.

Diabetes

Two of the basic principles of surgical management for any patient with diabetes are: (i) a thorough knowledge

of the patient's medical history, current treatment regimen, and level of glycemic control over time, and (ii) minimizing surgical therapy in poorly controlled diabetic patients.

The medical management of diabetes mellitus has changed markedly in the past 10–15 years (122). Landmark studies in the 1990s demonstrated a reduced risk of retinopathy, nephropathy, and neuropathy in diabetic patients who intensively managed their glycemic control through diet, exercise, and medications. Recognition that intensive therapeutic regimens could decrease blindness, amputation, and kidney failure, among other positive outcomes, dramatically shifted the foundations of diabetes care. Patients are now counseled and educated in proper ways to bring blood glucose levels as close to normal as possible, with the goal of preventing diabetic complications or reducing the progression of existing complications.

In today's dental office, it is uncommon to encounter patients with type 1 diabetes whose medical management regimen involves injection of insulin only once or twice a day, a once common regimen. Instead, the type 1 patient will more commonly be using multiple injections of insulin daily, or will use a subcutaneous insulin infusion pump. Type 2 patients who might have been managed with a single oral drug regimen 10 years ago will, today, often take multiple medications, including insulin injection. The state of diabetes care is always in flux, as research is evaluated concerning the risks and benefits of various therapies. Intensive management of blood glucose can increase the risk of severe hypoglycemia, which can be life-threatening (204). Recent evidence suggests that intensively lowering glucose levels in people with type 2 diabetes may actually increase the risk of death from cardiovascular causes (205). The impact of this study on future care of patients with type 2 diabetes, if any, is unknown at the current time.

There is some evidence that better glycemic control decreases the risk for and severity of periodontal diseases, and that diabetic patients with periodontal disease respond more favorably to periodontal treatment when their glycemic control is good than when it is poor (123). Conversely, there are almost no data available on the impact of improved glycemic control on dental implant outcomes.

Only one small study has examined short-term implant outcomes in diabetic patients whose glycemic control ranged from good to poor (138). This study showed a 100% short-term survival rate for implants in diabetic patients with widely varying HbA_{1c} values. However, studies evaluating differences in implant survival rates between diabetic and non-diabetic patients, or between well-controlled and poorly controlled diabetic patients, are difficult to perform. Because the implant survival rate is so high in general, especially in the era of rough surface implants, detecting significant differences between a high survival rate in one group and a relatively high survival rate in the second group requires a large number of subjects. These studies are expensive to perform and demand longitudinal evaluation over long periods to have much clinical relevance. The clinician is left to extrapolate from the medical surgical literature on potential risks for dental implant complications in people with diabetes, an extrapolation which is inexact, at best. What is clear is that the mere presence of diabetes does not contraindicate dental implant therapy. Instead, each patient must be evaluated individually, and physician consultation is recommended for patients with poor glycemic control. Informed consent for diabetic patients should delineate potential risks and benefits of therapy, and should clearly outline possible adverse sequelae of treatment.

Most expert opinion suggests that oral surgical procedures, including periodontal and dental implant surgery, in diabetic patients with good glycemic control have a degree of complication risk similar to non-diabetic patients (123). Patients with poorer glycemic control may present an elevated risk of perioperative complications such as infection or delayed wound healing. To prevent such untoward events, the dental clinician must evaluate how well or how poorly controlled a patient is by attaining a history that includes the patient's past HbA_{1c} values (206). As a guideline for interpretation, the ADA recommends that diabetic patients achieve glucose control that will be reflected in an HbA_{1c} of less than 7% (135). If the HbA_{1c} is greater than 8%, the ADA recommends physician intervention in the patient's management regimen to improve glycemic control. The HbA_{1c} can be used to estimate roughly the average blood glucose levels of a patient over the preceding 2–3 months (Table 2.2).

Table 2.2 HbA_{1c} levels and approximate corresponding average plasma glucose levels

HbA_{1c} (%)	Average plasma glucose (mg/dl)
6	126
7	154
8	183
9	212
10	240
11	269
12	298
13	326
14	355

HbA_{1c}: glycosylated hemoglobin.

A consult should be sent to the diabetic patient's physician to determine the degree of glycemic control. The most objective means of making this determination is to request from the physician at least the last 2 years of

HbA_{1c} values. This allows the dentist to evaluate not just a single HbA_{1c} value, but a series of values to determine not only the level of glycemic control, but also the stability. The results of this consultation will be used not only to evaluate the potential for postoperative infection or wound healing problems, but also to determine the risk for intraoperative hypoglycemia (addressed later in this chapter).

The risk for postoperative surgical complications is probably greatest in those diabetic patients with the poorest glycemic control. Thus, a patient with an HbA_{1c} over 10% presents a higher risk of problems than a patient with an HbA_{1c} of 7%. Establishing good glycemic control before implant surgery is ideal.

There is some evidence, although not conclusive, that the use of perioperative antibiotics may improve survival rates of implants placed in patients with diabetes. For example, in one study a survival rate of 86.6% was seen in type 2 diabetic patients who did not receive perioperative antibiotics compared with a survival rate of 97.1% in diabetic patients who did receive antibiotics (133). An improvement in survival rates was also seen in non-diabetic subjects in the same study: 90.6% for those who did not receive antibiotics compared with 95.1% for those who received antibiotics. Somewhat greater survival rates were also seen in diabetic and non-diabetic patients who used a chlorhexidine mouthrinse postoperatively. More studies are needed before clear treatment guidelines can be established relative to the use of perioperative antibiotics as a means of improving implant survival in diabetic patients. However, because people with diabetes have a higher risk of infections generally, the use of antibiotics at the time of implant surgery may be prudent as a means of prevention of postsurgical complications. If a clinician generally does not use antibiotics at the time of or following implant placement, a similar protocol can be followed for well-controlled diabetic patients. Poorly controlled diabetic patients may benefit more from perioperative antibiotic therapy, but the clinician should question the overall risk for surgery in such a patient. Because dental implant treatment is usually elective, it may be better to work with the patient and physician to improve glycemic control before placing dental implants than to work through infection or poor wound healing problems after surgery. A caveat for implant therapy is that postsurgical infections can happen in any patient after any surgical procedure. Just as infections occur in non-diabetic patients, good glycemic control in diabetic patients does not completely eliminate the risk for such infections after implant surgery.

A potential major complication in therapy for diabetic patients is in-office hypoglycemia. When severe, hypoglycemia can result in seizures, coma, and even death. One of the major risks of today's more intensive medication regimens for diabetes is hypoglycemia. For example, in the classic Diabetes Control and Complications Trial (DCCT) of treatment regimens for type 1 diabetes, individuals using intensive insulin regimens were three times more likely to suffer severe hypoglycemia than were people using conventional insulin regimens (205). Over 30% of these severe hypoglycemic episodes resulted in seizures or coma, and more than one-third had no warning signs or symptoms before their occurrence.

The risk for hypoglycemia is greatest in those diabetic patients who use insulin, although other medications can cause hypoglycemia. Dentists must know all of the medications being taken by diabetic patients, and should assess each medication for its hypoglycemic risk. Insulin works to allow glucose to enter cells, such as muscle cells, where the glucose is used for energy (122). As glucose leaves the bloodstream and enters the cells, the blood glucose level decreases. The time of peak insulin activity coincides with the time of greatest movement of glucose out of the bloodstream and into the tissues. Thus, peak insulin activity is associated with the greatest risk of hypoglycemia.

Numerous insulin preparations are available today, and each has its own pharmacodynamics and time of peak activity (Table 2.3). Clinicians should be aware of which insulin preparations a patient uses, and should assess the potential for peak insulin activity during the scheduled dental appointment. For example, if a patient with an 8 a.m. dental appointment injects short-acting insulin such as lispro or aspart just before eating breakfast at 7 a.m., peak insulin activity and the lowest blood glucose levels will likely take place during the dental appointment. This increases the potential for hypoglycemia occurring in the dental office.

Table 2.3 Types of insulin preparation

Type of insulin	Insulin classification	Onset of activity	Peak activity	Duration of activity
Glargine	Long-acting	6–8 h	"Peakless" (has no peak in activity)	> 24 h
Detemir	Long-acting	1–2 h	Relatively flat (minimal peak)	Up to 24 h
Ultralente	Long-acting	6–10 h	12–16 h	20–30 h
Lente	Intermediate-acting	3–4 h	4–12 h	16–20 h
NPH	Intermediate-acting	2–4 h	4–10 h	14–18 h
Regular	Short-acting	30–60 min	2–3 h	4–12 h
Lispro, Aspart, Glulisine	Rapid-acting	15 min	30–90 min	< 5 h

Because many people with diabetes inject several types of insulin each day, it may be difficult to avoid a time of peak activity when performing dental treatment. This is not a problem so long as the dental team is aware of the signs and symptoms of hypoglycemia and appropriate treatment regimens. A very common insulin regimen in the USA today for people with type 1 diabetes is an injection of rapid-acting insulin before each meal (aspart, lispro, or glulisine) and an injection of long-acting insulin once a day (ultralente, detemir, or glargine). Because insulin will allow glucose to move into the tissues, and thus decrease blood glucose levels, it is important for the dentist to ask the patient whether he or she has eaten their usual meal before the appointment. If not, then the level of carbohydrate being absorbed from the gut may be inadequate to sustain normal blood glucose levels and the patient may become hypoglycemic. This is especially true of a patient who has taken a short-acting insulin, as these insulin preparations rapidly decrease blood glucose levels.

In addition to insulin, several other injected medications have come on the market since 2005 for use by people with diabetes. Pramlintide is an injected agent taken primarily by type 1 and type 2 diabetic patients who use insulin. Pramlintide slows the rate at which food is released from the stomach into the small intestine and decreases hepatic glucose production. Because it slows stomach emptying and delays absorption of carbohydrate from the gut, pramlintide can result in severe hypoglycemia if the patient's insulin dose is not adjusted accordingly. Pramlintide has a very high risk of hypoglycemia, and carries a US Food and Drug Administration (FDA) "black box warning" owing to this serious potential side-effect (122).

Exenatide is a synthetic version of an incretin hormone called exendin-4, and is used by people with type 2 diabetes who also take oral medications (122). Exenatide is usually injected in the morning before breakfast and in the evening before dinner. It stimulates insulin secretion from the pancreas, but only in response to increased glucose in the bloodstream which follows a meal. Exenatide also slows emptying of the stomach after a meal, which prevents a sudden rise in blood glucose, and it decreases hepatic glucose production. Exenatide is a relatively safe drug with a low incidence of hypoglycemia because it only stimulates insulin production when the body needs more insulin after a meal. Exanatide can increase the risk of hypoglycemia associated with the use of oral agents that directly stimulate insulin secretion, such as the sulfonylureas and meglitinides.

People with type 2 diabetes commonly take oral medications to aid in glucose control and metabolism (Table 2.4). Many of these drugs increase pancreatic insulin secretion, which increases the risk for hypoglycemia as higher insulin levels result in more glucose moving into the tissues from the bloodstream. Before dental treatment, it is important for the dentist to make sure that a diabetic patient taking one of these agents has eaten. Conversely, there are various oral medications that pose very little risk for hypoglycemia. It is incumbent upon the dental treatment team to evaluate all patient medications and develop an individual assessment of each diabetic patient's risk for in-office hypoglycemic events (206).

Smoking

The primary means of preventing smoking-related dental implant complications are to deny dental implant

Table 2.4 Oral medications for diabetes care

Group	Agents	Risk of hypoglycemia	Action
Sulfonylureas	Glyburide Glipizide Glimepiride	High High Moderate	Stimulate insulin secretion from pancreas
Meglitinides	Repaglinide Nateglinide	Moderate Moderate	Stimulate rapid insulin secretion from pancreas
Biguanides	Metformin	Low	Block production of glucose by liver; improve tissue sensitivity to insulin
Thiazolidinediones	Rosiglitazone Pioglitazone	Low Low	Improve tissue sensitivity to insulin
α-Glucosidase inhibitors	Acarbose Miglitol	Low Low	Slow absorption of carbohydrate from gut; decrease postprandial peaks in blood glucose
DDP-4 inhibitors (called gliptins)	Sitagliptin Vildagliptin	Low Low	Stimulate pancreatic insulin secretion only after a rise in glucose level after a meal; block hepatic glucose production
Combination agents	Metformin + glyburide Metformin + glipizide Metformin + rosiglitazone Metformin + pioglitazone Glimepiride + rosaglitazone	High High Low Low Moderate	Combine actions from two different drug classes, as described above; level of risk for hypoglycemia depends on individual drugs in the combination agent

therapy to the smoking patient, or to recommend smoking cessation. When the results of some of the early research on smoking were published many clinicians considered smoking to be a relative contraindication to implant placement and they would not place implants in such patients. However, more research has been performed and dental implant technologies have changed over time, resulting in a re-evaluation of the relative risk of smoking for poor implant outcomes.

As discussed above, smoking seems to have its primary negative effects on machined surface implants, on implants placed in less dense bone, and on implants placed in bone developed by bone grafting, such as a sinus or ridge augmentation procedure. Today, machined surface implants are used infrequently, as implants with roughened or microroughened surfaces have come to dominate the market. Thus, the overall risk of implant failure associated with smoking has diminished simply through changes in the implants themselves.

If the clinician plans to place implants in the maxilla or another area with poor bone density, smoking may be considerably more important in assessing the individual patient's risk for poor outcomes (Fig. 2.15a–e). Likewise, if an augmentation procedure such as a sinus augmentation or ridge augmentation procedure is planned, the

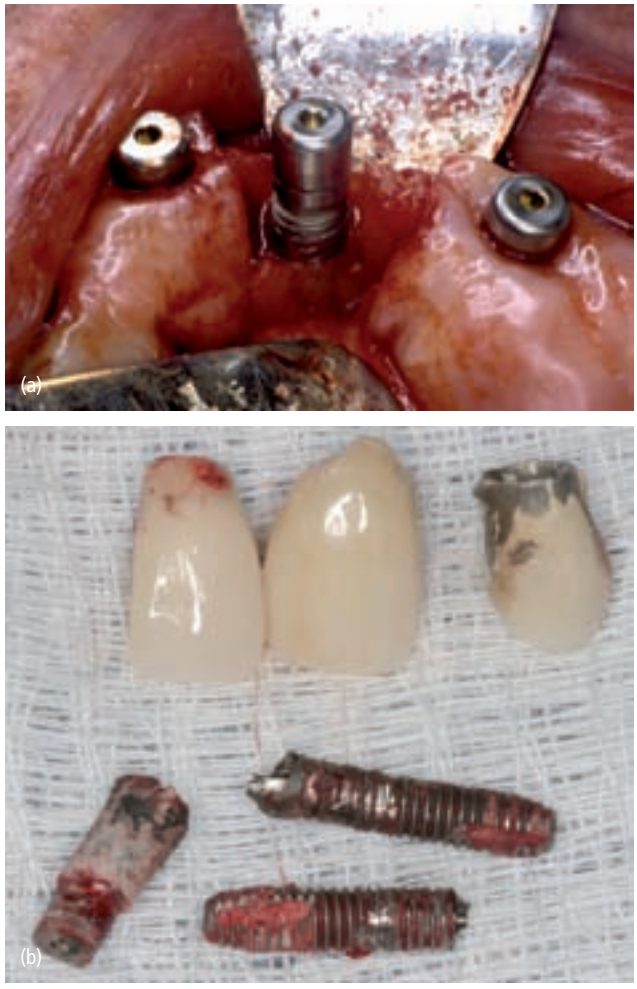


Fig. 2.15 Smoking patient with long-term failure of all implants: 45-year-old Hispanic male who smoked two packs of cigarettes per day for over 20 years; six maxillary implants had been placed 7 years before these photographs. (a) Flap reflection in maxillary anterior demonstrates significant loss of crestal bone height; implants were deemed to have hopeless prognosis; (b) trephines were used to remove implants; (c) ridge form was restored with freeze-dried bone allograft; (d) resorbable collagen membrane placed over augmented ridge; (e) flaps closed over augmented ridge. The patient did not quit smoking and is at high risk for complications if future implant therapy is performed. (Courtesy of Dr Rachel Schallhorn, San Antonio, Texas.)

smoking patient may be at greater risk for implant failure. It is worthwhile to keep in mind that while smoking may increase the failure rate of implants placed in low-density bone or in augmented bone, the survival rates of such implants are still above 80–85% in most studies, and well over 90% in others. Thus, the clinician must weigh the potential risks and benefits of dental implants for each patient. If a somewhat lower survival rate than normal is acceptable to the patient who smokes and to the clinician given the potential benefits of implant therapy, treatment can proceed. If an increased chance of failure is deemed too high, options other than implant therapy may be more appropriate.

Since clinicians generally do not deny implant therapy to most healthy smoking patients, the other means of preventing poor implant outcomes is smoking cessation. Despite the need for evidence-based practice guidelines in this area, few studies have examined the potential effects of smoking cessation on implant outcomes. In the most frequently referenced study on this topic, a protocol was developed in which smoking patients stopped smoking 1 week before dental implant placement, followed by 8 more weeks without smoking to allow initial healing (140). A prospective evaluation of this protocol in a pilot trial with 78 patients having over 200 implants showed an implant failure rate of 12% in the patients who followed the smoking cessation protocol compared with 38% in those who continued to smoke (207). This suggests that a preoperative and postoperative smoking cessation protocol may benefit the patient. However, it should be noted that this study included only machined surface implants, so the effect of smoking cessation on implants with other surface characteristics is unknown. In addition to its potential positive effect on implant outcomes, smoking cessation will benefit the overall health of the patient as well as his or her periodontal health. Thus, smoking cessation recommendations should be a matter of routine dental office protocols.

A key point in managing the smoking patient is to obtain thorough and detailed informed consent. While this is true for any implant patient, the smoking patient should be informed about the possible negative impact of their smoking habit on implant outcomes. In addition, the negative impact of smoking on remaining teeth in the partially edentulous patient should be discussed. In the informed consent, the clinician can specifically identify smoking as a factor that could increase the chance of implant failure so that there is no question whether or not the patient had been informed and counseled.

Immunodeficiency

Complications following dental procedures have been evaluated in people with HIV and AIDS. Many of these studies were performed before the advent of HAART. The complication rate in 331 patients with AIDS who received over 1800 outpatient dental procedures, including endodontic, restorative, periodontal, and surgical therapy, revealed a complication rate of only 0.9% (208). This is less than the 2% complication rate seen following periodontal surgery in subjects without HIV or AIDS (209).

Studies of postextraction complications generally show similar rates in patients with HIV compared to those without HIV (208, 210, 211). The most common complication in HIV-positive patients is alveolar osteitis, just as it is in HIV-negative patients. However, some studies show higher rates of postextraction complication rates in HIV-positive subjects (212).

Most of the information available on postsurgical complications in HIV-positive patients on HAART comes from the medical literature, with studies of implantable devices coming mainly from orthopedics (151). In some studies, higher rates of wound sepsis have been seen in HIV-positive patients following orthopedic surgery compared with HIV-negative patients, while in others, no difference is seen between patient groups. In a large study of postsurgical outcomes, 332 HIV-positive individuals were matched with 332 HIV-negative subjects by age, gender, type of surgery, and location of surgery (213). About two-thirds of the HIV-positive individuals were taking HAART, while the rest were not. A wide variety of surgical procedures was included, such as bowel resection, cardiothoracic procedures, hernia repair, joint replacement, mammoplasty, laparoscopy or laparotomy, and cholecystectomy. There was no significant difference in the rate of complications between patient groups, except for a higher incidence of pneumonia in the HIV-positive group. Among the HIV-infected patients, a viral load of over 30 000 copies was associated with a three-fold increased risk of postsurgical complications compared with subjects having a viral load of less than 30 000 copies. However, CD4 cell counts less than $200/mm^3$ were not associated with an increased risk of complications. These results suggest that patients with HIV can be treated surgically with a similar risk for complications, but that examination of viral load may be beneficial in risk assessment.

The effect of HAART on complication rates following dental procedures is unknown. No research has been performed similar to that described above for other surgical procedures. However, some general guidelines are useful in managing HIV-infected patients who are being evaluated for dental implant therapy:

- Determine duration of HIV infection.
- Evaluate medical, dental, and social history:
  - determine the presence or absence of other significant systemic conditions:
  - viral infections (e.g. hepatitis, cytomegalovirus)

  - blood dyscrasias
  - liver problems
  - other systemic conditions
  - infection history
  - prior surgical history
  - evaluate past dental treatment (frequency/consistency, preventive care, types of treatment)
  - evaluate social history (habits, drug or alcohol use, tobacco).
- Physician consultation:
  - general physical assessment
  - infection history
  - prior surgical history
  - viral load
  - CD4 cell count
  - assess risk for postsurgical infection
  - recommendations for surgical treatment plan.

HIV infection can occur in individuals who are otherwise healthy. HIV can also occur in people with a multitude of systemic problems. Therefore, an overall physical assessment is important. Clinicians should focus on medical, dental, and social history to determine whether any risk factors for intraoperative or postoperative complications exist. Physician consultation is often recommended because the dentist can request the results of recent laboratory testing for CD4 cell count and viral load. High viral load or low CD4 cell counts (< 200/mm^3) may increase the risk of complications after implant surgery. The physician can also advise on any other systemic conditions or therapies that may affect the implant surgical treatment plan for a given patient.

Many clinicians prefer to place HIV-positive patients on antibiotics before and after oral surgical procedures. There is no evidence that this practice improves implant survival and little evidence that it decreases postoperative complication rates. However, most of the case series examining implant therapy in HIV-positive patients routinely used preoperative and postoperative antibiotics in their treatment protocols (151–153). Several studies of postoperative infections after tooth extraction have challenged the notion that HIV-positive patients require antibiotics after treatment, since infection rates were similar between HIV-positive and HIV-negative individuals (210, 211). The need for postoperative antibiotics following implant surgery in patients without HIV is controversial; for people with HIV the question simply has not been studied enough to allow evidence-based clinical guidelines. Therefore, the clinician must assess each patient's risk individually and determine whether or not to use antibiotics.

The CD4 count measures the number of T-helper lymphocytes present. The CD4 count is commonly tested in HIV-positive individuals to provide an approximation of infection risk (214). In general, the CD4 count decreases as HIV disease progresses. A normal CD4 count is approximately 500–1500 cells/mm^3. HIV-infected people with CD4 counts below 200/mm^3 are considered to have AIDS. While CD4 counts often decrease in early HIV disease, the use of HAART results in increased CD4 counts. Viral load tests are reported as the number of viral copies/mm^3. Of course, there is no "normal" HIV viral load. A high viral load indicates that the virus is replicating and the risk for disease progression is high. A viral load of 5000–10 000 copies is considered high, but the number of copies can be higher than one million. Viral loads of 200–500 copies are considered relatively low. Patients may report that their viral load test showed the virus was undetectable. This does not mean that the patient is necessarily free of HIV; it means that the number of HIV copies is not detectable by the methods used. However, an "undetectable" viral load is associated with a lower risk of progressive HIV disease. Clinicians should request the most recent CD4 counts and viral load counts in their consultation with the patient's physician. The viral load does not give a measure of risk for postoperative infection, but is a means of evaluating the current status of the patient's HIV disease. A low CD4 count may support use of antibiotics.

Immunosuppressant therapy is a mainstay for managing many patients with organ transplants and certain forms of cancer (19). Wound healing depends on the body's ability to mount an effective immune and reparative response. Immunosuppressant therapy often reduces white blood cell (WBC) counts. As the number of WBCs decreases, the risk of infection increases. This includes infections that may occur following dental implant procedures.

A normal WBC count is approximately 4500–10 000/mm^3. When the WBC count falls below 1500–3000/mm^3, the risk of infection increases (215). The WBC count includes a count of neutrophils, eosinophils, basophils, lymphocytes, and monocytes. The absolute neutrophil count (ANC), which includes only neutrophils, is often used as a means of assessing risk for infection in immunosuppressed patients. A normal ANC is greater than 1500/mm^3. Mild neutropenia is associated with an ANC of 1000–1499/mm^3, moderate neutropenia is an ANC of 500–999/mm^3, and an ANC below 500/mm^3 is severe neutropenia.

Patients on immunosuppressant therapies should have the ANC determined before any surgical treatment, in consultation with the patient's physician. The lower the ANC, the greater the risk of infection. Even mild neutropenia can increase the risk of infection, but the risk is severe in those with an ANC below 500/mm^3. Because most dental implant therapy is elective, or can at least be postponed if necessary, immunosuppressed patients with an ANC below 1000/mm^3 should not undergo implant surgery. Those with an ANC between

1000 and 1500/mm^3 should also be postponed until the ANC reaches a normal level; however, in consultation with the physician such patients may undergo emergent procedures. In general, antibiotics should be prescribed before and after surgery, until wound healing has been attained, in patients with an ANC below the normal range.

Cancer therapy

Chemotherapy can induce immunosuppression, bone-marrow suppression, and local cytotoxicity of oral tissues (158). This results in increased risk of hemorrhage, infection, mucositis, xerostomia, and mucosal ulceration. Granulocytopenia and thrombocytopenia are commonly induced by chemotherapy. Therefore, if dental implant treatment is planned, surgery should be delayed until the acute effects of chemotherapy have subsided.

The patient's physician should be consulted to determine the current health status, function of bone-marrow elements, and state of immunosuppression. Platelet count, hematopoietic parameters, and immune function can be assessed via laboratory analysis. Surgery should not be performed until WBC and ANC are within normal limits to decrease the risk of infection. Red blood cell count, platelet count, hemoglobin, and other parameters should be discussed with the physician to ensure that the patient can tolerate surgery with minimal risk of hemorrhage. Antibiotic prophylaxis is generally considered in patients who have received chemotherapy in the recent past, and can be discussed with the consulting physician.

For patients who have received radiation therapy to treat head and neck cancers, the dentist should consult the oncologist to determine the exact fields of radiation and the total radiation dose. Radiation doses greater than 45 Gy are associated with lower implant survival rates (159). If implants are planned for regions of the mouth that did not receive radiation, an implant success and survival rate similar to a healthy patient can be anticipated (161). If implants are planned in previously irradiated bone or, especially, in bone that was grafted following a resection, the clinician and patient must appreciate the decreased chances of implant survival (161). However, because ablative cancer surgery can be extensive and can so dramatically reduce the patient's ability to function, the risk–benefit ratio in these patients often leans toward placing dental implants in the hope of being able to retain some type of prosthesis that can restore at least partial function, with full knowledge that implant failures may occur (160).

As discussed above, a lack of data demonstrating a beneficial effect of hyperbaric oxygen therapy on implant outcomes does not support inclusion of hyperbaric oxygen in routine treatment protocols for previously irradiated patients. There may be some individuals for whom the oncologist recommends hyperbaric oxygen, for example those receiving very high radiation doses, or patients with extensive resection and grafting. Hyperbaric oxygen treatment is expensive and may not be available in many communities.

For any cancer patient, it is important to eliminate potential sources of oral infection. Thus, periodontal diseases, caries, endodontic pathology, and other inflammatory conditions should be treated and the patient should be followed at regular, short intervals to ensure a persistent state of health. Before extensive implant treatment plans are developed, consultation with the physician and patient should include discussions of anticipated patient survival. Many head and neck cancers have high long-term survival rates, while others are associated with a poor prognosis in the short or long term.

Treatment

Myocardial infarction

If angina occurs during dental treatment, the procedure should be stopped. The patient should be placed in a semi-supine position and 100% oxygen should be administered. In addition, a 0.3 or 0.4 mg tablet of nitroglycerin should be placed sublingually. The nitroglycerin may be repeated at 5-minute intervals if pain persists, but the minimal dose required should be used because excessive amount of the drug may induce hypotension (38).

Pain that persists for longer than 15–20 minutes, along with other signs and symptoms of MI, may require transfer to the hospital emergency room. These signs and symptoms may include diaphoresis, nausea, syncope, or hypertension (216). In case of cardiac arrest, resuscitative measures should be initiated (217).

Cerebrovascular accident

Dental staff should demonstrate an empathetic and supportive approach in understanding the patient's physical and emotional limitations and allocate extra time for communication and clinical procedures (31, 218). Hemiplegic stroke victims may require assistance while walking or transferring to and from the dental chair (32). Oral hygiene aids and instructions should be individualized based on the patient's ability to perform effective oral care (31).

Recommendations and treatment goals should be realistic and modifiable, have clearly defined steps, and involve the personal care givers as necessary (32). Prevention of oral disease caused by xerostomia, dietary changes, and ineffective oral hygiene may be accomplished by reinforcing oral care practices, topical applica-

tion of fluoride, daily rinses with chlorhexidine, and frequent recalls (32). Oral rehabilitation with fixed dental prostheses reduces attrition and wear of the opposing dentition in patients with stroke-related oral parafunction. Fixed or removable prostheses with porcelain occlusion are to be avoided (36).

Valvular prosthesis placement

In patients with valvular heart disease, as with other systemic diseases, patient selection is the critical factor for implant survival. In most cases an appropriate healing response allows for, if not ensures success (19).

Patients at risk of bacterial endocarditis must take excellent care of their teeth and gums to prevent infection. If symptoms of infection occur, such as sore throat, fever, joint pain, swelling, chills, and body aches, a physician should be consulted promptly.

Osteoporosis

If accelerated peri-implant bone loss with no clinical signs of peri-implant disease occurs during the maintenance phase, the patient should be examined for occlusal overload and referred to a medical specialist such as an endocrinologist, for re-evaluation of the osteoporotic/osteopenic therapy regimen (50).

Cooper (178) noted that the significant advantages associated with dental implants in edentulous subjects and the high degree of success of implants in the dense cortical bone of the edentulous mandible (163) indicate that nearly all edentulous patients can benefit from dental implants with limited risk of failure.

Paget's disease of the bone

Current thought is that the dental implants are contraindicated in areas affected by PDB (219) although there is currently no literature to support this rationale. Even in the absence of PDB, if the quality of the bone in question is determined to be poor, implant therapy should proceed with caution or not be considered at all. However, if the bone in question is thought to be of acceptable quality, even in those patients with mild or remissive PDB, dental implants may still be a viable prosthetic consideration. If the bone is determined to be of poor quality upon clinical placement of implants, it may still be possible to obtain a favorable result (183).

Psychiatric disorders

Psychiatric disorders are not necessarily a contraindication to dental implant treatment. On occasion dental implant treatment can provide valuable psychologic support.

If any doubt exists about the effect of a psychiatric disorder on the prognosis of implant treatment, the opinion of a psychiatrist should be obtained.

Alzheimer's disease

Niessen and Jones (76) reported the following: To some cognitively intact people, the dental office is not perceived as a particularly familiar, pleasant environment. The patient with Alzheimer's disease, who was a regular patient before the illness began, may now perceive the dental office as threatening and unfamiliar. The noise associated with the dental handpiece or high-volume suction can be particularly distressing.

In addition, patients with Alzheimer's disease often show frustration and fear when they cannot understand verbal questions, instructions, or information, or when they are placed in an unfamiliar environment. Fear and frustration can result in behaviors that include threatening gestures, increased voice volume, increased restlessness, agitation, and hostility (220). The treatment team must use verbal and non-verbal communication to alleviate the patient's fears.

Alzheimer's disease affects approximately 1.5 million people in the USA. As the population increases, the number of people with Alzheimer's disease will increase. Families provide the majority of care for these patients and the effects of this disease on families can be devastating. The goals of dental care are to prevent loss of oral health function despite the loss of cognitive function. Providing dental care to patients with a dementing illness requires modification of management techniques, particularly greater use of non-verbal communication and alterations in verbal communication patterns. Appropriate treatment planning and aggressive prevention are critical to the success of the dental treatment plan and maintenance of oral health (76).

Parkinson's disease

PD is a well-known neurologic disorder similar to Alzheimer's disease. Patients with PD are usually prescribed levodopa. It is necessary to avoid inducing any stress in patients taking levodopa, because stress could elevate patients' endogenous catecholamines or blood pressure to dangerous levels. The injection of regional anesthetic agents that contain large amounts of epinephrine when performing surgery on patients treated with levodopa can also elevate catecholamine levels or blood pressure.

Midazolam may be required if the patient has a severe gag reflex and needs impressions. Midazolam is also helpful to reduce stress caused by anxiety and can further help maintain cardiovascular stability during implant surgery performed with regional anesthesia. It

also causes less respiratory change and fewer neurovascular effects. The efficacy and safety of parenteral sedation, which is used not only during implant surgery (221) but also during other oral and maxillofacial surgical procedures (222, 223) in combination with other sedatives such as propofol (224) or fentanyl (225), have been demonstrated previously.

According to Heckmann *et al*. (192), dental implants can provide great benefits to severely handicapped PD patients, including improvements in both chewing and predigestion capacity. The use of regional anesthesia in combination with intravenous midazolam is the treatment of choice for patients with systemic disease undergoing implant surgery.

Pharmacologic considerations

Corticosteroids

For those taking corticosteroids for systemic disease, contact between the clinician and the physician is imperative. The range of treatment options and their advantages and disadvantages should be carefully weighted in relation to the patient's need and wishes. An excellent standard of oral hygiene is essential to minimize the possibility of infection.

Despite all precautions, an acute adrenal crisis may occur and the dentist needs to be prepared to manage the condition. Signs and symptoms of crisis include hypotension, weakness, nausea, vomiting, diarrhea, dehydration, abdominal cramping, irritability, headache, and fever. Acute adrenal crisis is life threatening and immediate treatment consists of 100 mg of hydrocortisone administered intravenously or intramuscularly. The patient should be transferred to a hospital facility as soon as possible (226).

Bisphosphonates

The AAOMS (102) uses the following staging categories for patients who develop or have been diagnosed with bisphosphonate-related osteonecrosis of the jaw:

- Stage I: Exposed/necrotic bone in patients who are asymptomatic and have no evidence of infection.
- Stage II: Exposed/necrotic bone in patients with pain and clinical evidence of infection.
- Stage III: Exposed/necrotic bone in patients with pain, infection and one or more of the following: pathologic fracture, extraoral fistula, or osteolysis extending to the inferior border.

Treatment strategies are as follows (102):

- Stage I: No surgical treatment is indicated. Patients benefit from oral antimicrobial rinses, such as chlorhexidine 0.12%, and do well with this type of conservative treatment. Patients should be followed up every 3–4 months (93)
- Stage II: Patients benefit from oral antimicrobial rinses in combination with antibiotic therapy. Most of the isolated microbes have been sensitive to the penicillin group of antibiotics. For those with a penicillin allergy, quinolones, metronidazole, clindamycin, doxycycline, and erythromycin can be dispensed. Microbial cultures should also be analyzed for the presence of *Actinomyces* species of bacteria. If the microbe is isolated, then the antibiotic regimen can be adjusted. In some refractory cases, patients may require combination antibiotic therapy, long-term antibiotic maintenance, or a course of intravenous antibiotic therapy. Pain control may also be indicated.
- Stage III: Patients typically have pain that may impact quality of life. Surgical débridement/resection in combination with antibiotic therapy may offer long-term palliation with resolution of acute infection and pain.

Regardless of the stage of the disease, mobile segments of bony sequestrum should be removed without exposing the uninvolved bone. The extraction of symptomatic teeth within exposed, necrotic bone should be considered because it is unlikely that the extraction will worsen the necrotic process (102).

The risks and benefits of continued bisphosphonate therapy should be decided in consultation with the treating physician and the patient to determine whether modification or cessation of the therapy is possible.

Anticoagulants

During the past few years, new evidence has accumulated that indicates an increased risk of thrombotic outcomes with the discontinuance of low-dose aspirin therapy (166, 227, 228). The continuation of aspirin during more extensive procedures (e.g. complicated extractions, bony impactions, implant placement, osteotomies) and the use of other antiplatelet medications have not been thoroughly investigated with respect to postoperative bleeding complications, but the same concerns with the loss of antithrombotic benefit of antiplatelet medications must be carefully considered before discontinuation of these medications (166).

Bleeding postextraction and dental implant placement can be controlled by standard local hemostatic measures including suturing and direct packing with gauze, resorbable gelatin sponge, oxidized cellulose or microfibrillar collagen (166). Fibrin glue or a mouthwash with tranexamic acid also gives satisfactory hemostasis (103).

If bleeding is controlled after surgery, the patient should be dismissed and given a 7-day follow-up appointment and the telephone number of the office with instructions to call if bleeding occurs (229). The

occurrence of additional risk factors for bleeding should prompt the treating clinician to be more cautious (i.e. to place more sutures and to prescribe in advance the use of antifibrinolytic agent, such as topical 4.8% tranexamic acid, for up to 7 days.)

Garfunkel *et al.* (229) advise that if there is bleeding, biting on a moist gauze, or a gauze pad soaked in tranexamic acid, or a moist tea bag with firm pressure for 30 minutes might eliminate the bleed. With a bleeding patient, it is important to establish whether the situation is urgent and when the patient will need admission for intravenous fluids or reversal of anticoagulation. This may well be the case if the patient is losing large quantities of blood or is hypotensive (hypovolemic).

In addition, Garfunkel *et al.* (229) state that to stop oral bleeding, clots should be washed out with warm saline solution, the bleeding area should be identified, a local anesthetic injection containing epinephrine (adrenaline) should be administered, a sterile gauze pad soaked with tranexamic acid should be pressed firmly over the extraction socket for 10–15 minutes, and suturing of the socket should be considered, with silk sutures to enable tighter suturing. If the patient continues to bleed, desmopressin acetate (deamino-8-D-arginine vasopressin) may help. This synthetic analogue of vasopressin induces the release of factor VIIIC, von Willebrand's factor, and tissue plasminogen activator from storage sites in the endothelium. Desmopressin offers an alternative to blood products to control bleeding risk in patients with moderate and mild hemophilia (230). It is given as an intranasal spray (1.5 mg desmopressin per ml with each 0.1 ml pump spray delivers a 100–150 μg dose).

Antibiotics

The benefits of prophylactic antibiotics are well recognized in dentistry.

Specifically related to implants and antibiotics, a study by Dent *et al.* (231) showed that significantly fewer implant failures occurred when preoperative antibiotics were used. In that study there was "overall approximately a 2:1 risk of failure if preoperative antibiotics" were not used. Moreover, a review of the literature by Sennerby and Roos (232), concerning determinants of clinical success of osseointegrated implants, noted that a "lack of preoperative antibiotics, and smoking may lead to higher implant failure rates".

Lastly, in a study by Wagenberg and Froum (233), it was reported that patients with penicillin allergies were 3.34 times more likely to experience implant failure, when an immediate implant protocol was used, than patients who were able to use penicillin preoperatively.

However, the routine use of antibiotics in the placement of endosseous dental implants remains controversial. The preoperative or postoperative use of antibiotics, the type used, and the duration of coverage should be left to the discretion of the surgeon after careful assessment of the patient's history (234).

Diabetes

A diabetic patient with a postoperative infection is handled much like a non-diabetic patient with a similar presentation. Local access and drainage of infected areas, combined with systemic antibiotics, are the primary treatment modalities. Slow wound healing in a diabetic patient after implant surgery requires patience to allow healing to progress and attention to thorough plaque removal and cleansing to prevent secondary infection.

Prevention of hypoglycemia during implant treatment is best accomplished by patient history and knowledge of medications used by the patient, assessment of HbA_{1c} values at the time of initial patient evaluation and treatment planning, and immediate preoperative assessment of capillary blood glucose using the patient's glucometer (206). As mentioned previously, the dentist should consult with the physician and obtain HbA_{1c} values for at least the past 2 years. The risk for in-office hypoglycemia is greater in patients with good glycemic control than it is in those with poor glycemic control. The patient with good glycemic control has average glucose levels closer to normal than does the patient with poor control. A normal fasting glucose level is between 70 and 110 mg/dl. After a meal in a non-diabetic person, glucose levels rise but fall quickly as the carbohydrate stimulates release of insulin from the pancreas, activation of insulin receptors on muscle cells to allow the entry of glucose, and movement of glucose out of the bloodstream and into the muscle tissue. A normal glucose level 2 hours after a meal is below 140 mg/dl.

In general, symptoms of hypoglycemia occur with blood glucose levels below 60 mg/dl. The closer the diabetic patient is to this glucose level throughout the day, the more likely they are to drop below the threshold at which symptoms of hypoglycemia will occur. Conversely, the patient with high glucose levels throughout the day, and therefore higher HbA_{1c} values, is less likely to have the glucose level drop below the threshold for hypoglycemia. It should be noted that people with very high glucose levels may have symptoms of hypoglycemia even with glucose levels higher than 60 mg/dl, especially if a very high glucose level drops rapidly.

The returned physician consultation with the HbA_{1c} values from the past 2 years gives the dentist an important piece of information when evaluating the patient's risk for in-office hypoglycemia. A patient with a consistently high HbA_{1c}, over 8% for example, has a lower risk of hypoglycemia than a person with a consistently low HbA_{1c}, for example below 7%. Patients with HbA_{1c} values that swing widely can be very difficult to assess, but

caution should be exercised and signs or symptoms of hypoglycemia evaluated throughout treatment in these individuals.

An important means of assessing the risk for hypoglycemia during a given dental appointment is to have the patient check the blood glucose level with the patient's glucometer just before treatment begins (206). This allows the dentist to know where the blood glucose level is before any treatment has begun. If the pretreatment glucose level is low or even in the normal range (<100 mg/dl) and the procedure may be prolonged, providing the patient with a small amount of carbohydrate such as 4–6 ounces of juice (about 15–20 g of carbohydrate) may bring the glucose level up 30–40 mg/dl to a point where the risk for hypoglycemia is diminished. Having diabetic patients bring their glucometer to each appointment is an office policy that may help prevent hypoglycemia or may allow accurate diagnosis of a hypoglycemic state if the patient becomes symptomatic. If symptoms occur, patients can use their glucometer to quickly determine the blood glucose level.

All members of the dental team should be familiar with the signs and symptoms of hypoglycemia:

- agitation/anxiety
- confusion
- sweating
- shakiness/tremors
- tachycardia
- dizziness
- feeling of "impending doom"
- seizures
- loss of consciousness.

Once these signs or symptoms appear, dental treatment should cease immediately. If the patient brought a glucometer to the dental appointment, he or she should immediately check the blood glucose level, if possible. To treat hypoglycemia in a conscious patient, the dentist should give approximately 15 g of oral carbohydrate in a form that will be rapidly absorbed. This is usually sufficient to increase glucose levels by 30–40 mg/dl in most patients. Four to six ounces of fruit juice or soda is usually adequate to relieve symptoms. Alternatively, 3 or 4 teaspoons of table sugar or an appropriate amount of hard candy may be given. Tubes of cake icing are easy to store and provide a rapid source of readily absorbed carbohydrate. Oral carbohydrate in these forms will generally elevate blood glucose within 10–20 minutes, with relief of symptoms. Changes in blood glucose can be confirmed by the patient testing again with the glucometer. If symptoms have not resolved in a short period or glucometer readings show persistent low blood glucose, another 15 g of carbohydrate should be given. If this does not relieve symptoms, emergency services should be called and the patient monitored until their arrival.

When the patient is sedated or unable to take food or drink by mouth, 25–30 ml of 50% dextrose or 1 mg of glucagon can be given intravenously. Giving 30 ml of 50% dextrose in water provides 15 g of carbohydrate directly to the bloodstream, and generally results in rapid reduction in symptoms of hypoglycemia. Glucagon injection results in glycogenolysis in the liver, releasing glucose from glycogen stores and rapidly increasing blood sugar levels. The patient should recover within 5–15 minutes following treatment. In the absence of intravenous access, 50% dextrose cannot be used. Instead, 1 mg of glucagon can be injected subcutaneously or intramuscularly at practically any location in the body. Glucagon is rapidly absorbed from the location of injection and results in rapid elevation in blood glucose levels. If it does not, a call for emergency medical assistance is warranted.

To summarize:

- Determine capillary blood glucose using glucometer, if possible, to confirm hypoglycemia (symptoms of hypoglycemia usually seen with glucose levels < 60 mg/dl).
- If the patient can take food by mouth, give approximately 15 g of carbohydrate:
  - 4–6 ounces of fruit juice or sugared soda
  - 3–4 teaspoons of table sugar
  - glucose tablets (carried by many diabetic patients) or hard candy
  - cake icing/frosting.
- If the patient cannot take food by mouth and intravenous access is present:
  - 25–30 ml of 50% dextrose (D50) given intravenously
  - 1 mg glucagon given intravenously.
- If the patient cannot take food by mouth and intravenous access is not present:
  - 1 mg glucagon given intramuscularly or subcutaneously.
- Monitor the patient for 1 hour; patients can assess glucose level using their glucometer.
- Call emergency medical services if the patient does not respond.

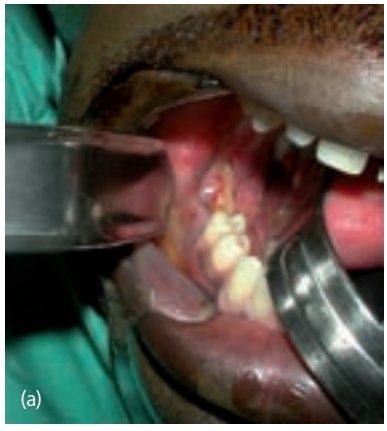
When a patient experiences symptomatic hypoglycemia in the dental office requiring emergency treatment, the patient should be monitored for approximately 1 hour after recovery to ensure complete recuperation. Patient evaluation of the blood glucose level by the glucometer can confirm a return to normal glucose levels.

Cancer therapy

Treatment of implant complications in cancer patients has many of the same limitations as initial implant placement surgery. If a patient undergoing chemotherapy

presents with an infection associated with dental implants, antibiotic therapy combined with incision, drainage, and débridement is the treatment of choice. However, the patient's overall health status may prevent immediate surgical débridement owing to a risk of bleeding or dissemination of infection. In those cases, antibiotic therapy may have to be used alone until the patient is stable enough for surgery, and patients may need to be managed in a controlled environment to allow appropriate assessment and treatment. Intravenous antibiotics and hospitalization may be required.

The major complication associated with radiation therapy is ORN (Fig. 2.16a, b). Treatment of ORN should be performed by a surgeon comfortable with managing such patients. In general, careful débridement of necrotic tissues is combined with antibiotic use to prevent infection (235). Débridement may result in loss of previously placed dental implants. The site must be allowed to heal completely and may require grafting before any attempt to place implants again. There is strong evidence that hyperbaric oxygen improves the treatment of ORN, and should be considered in such cases (236).



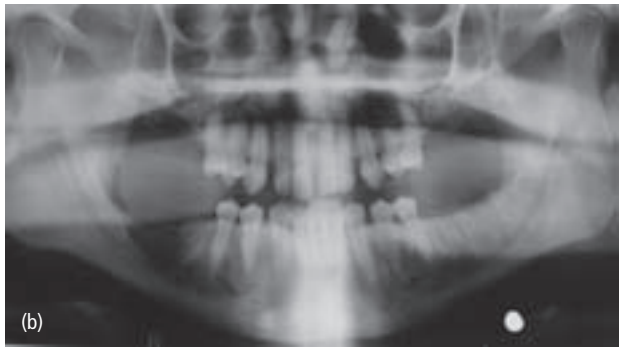


Fig. 2.16 Osteoradionecrosis: 53-year-old African–American male with history of squamous cell carcinoma of the tongue. The patient was treated with surgical removal of the lesion followed by 62 Gy of radiation to the right mandible, tongue, and floor of mouth. (a) Patient presented with pain and exposed bone in right posterior mandible; osteoradionecrosis arose spontaneously, with no precipitating trauma or dental treatment; (b) radiograph shows diffuse radiolucency in right posterior region. The patient responded poorly to treatment and eventually required mandibular resection. (Courtesy of Dr Wendell Edgin, San Antonio, Texas.)

Take-home hints

- Patient selection is the critical factor for implant success and survival in any medically complex situation.
- When medical conditions are managed wisely most patients with diseases discussed in this chapter have improved overall health with fixed replacements as opposed to removable appliances.
- Exceptional care must be taken so that any implants placed will be successful and safe for the clinician and the patient.
- It is essential to routinely review the literature and expect that protocols for patients with systemic diseases or taking medications will be regularly updated as our knowledge of dental implants advances.

References

1. Sonis ST, Fazio R, Setkowicz A, Gottlieb D, Vorhaus C. Comparison of the nature and frequency of medical problems among patients in general, specialty and hospital dental practices. *J Oral Med* 1983; **38**: 58–61.
2. McLundie AC, Watson WC, Kennedy GD. Medical status of patients undergoing dental care. An assessment. *Br Dent J* 1969; **127**: 265–71.
3. Scully C, Cawson RA. *Medical problems in dentistry*, 2nd edn. Bristol: Wright, 1987: 36–71.
4. Agerberg G, Carlson GE. Chewing ability in relation to dental and general health. Analyses of data obtained from a questionnaire. *Acta Odontol Scand* 1981; **39**: 147–53.
5. Atwood DA. Reduction of residual ridges: a major oral disease entity. *J Prosthet Dent* 1971; **26**: 266–79.
6. Zarb GA, Bolender CL, Carlson GE. *Prosthodontic treatment for edentulous patients*, 11th edn. St Louis, MO: Mosby, 1997: Chapter 22.
7. Smith RA, Berger R, Dodson TB. Risk factors associated with dental implants in healthy and medically compromised patients. *Int J Oral Maxillofac Implants* 1992; **7**: 367–72.
8. National Institutes of Health consensus developments, conference statement. Dental implants. *J Am Dent Assoc* 1988; **117**: 509–13.
9. Massie BM, Sokolow M. Heart and great vessels. In: Schroeder SA, Krupp MA, Tierney LM, McPhee SJ, eds. *Current medical diagnosis and treatment*. Norwalk, CT: Appleton & Lange, 1991.
10. Engel TR. Cardiovascular diseases. In: Rose LF, Kaye D, eds. *Internal medicine for dentistry*. St Louis, MO: Mosby, 1990: 401–13.
11. Whitney JD. The influence of tissue oxygen and perfusion on wound healing. *AACN Clin Iss Crit Care Nurs* 1990; **1**: 578–84.

12. Rabkin JM, Hunt TK. Infection and oxygen. In: Davis JC, Hunt TK, eds. *Problem wounds: the role of oxygen*. New York: Elsevier, 1988: 1–16.
13. Khadivi V, Anderson J, Zarb GA. Cardiovascular disease and treatment outcomes with osseointegration surgery. *J Prosthet Dent* 1999; **81**: 533–6.
14. Findler M, Galili D, Meidan Z, Yakirevitch V, Garfunkel AA. Dental treatment in very high risk patients with active ischemic heart disease. *Oral Surg Oral Med Oral Pathol* 1993; **76**: 298–300.
15. Findler M, Garfunkel AA, Galili D. Review of very high-risk cardiac patients in the dental setting. *Compendium* 1994; **15**: 58–66.
16. Levine E, Tzukert AA, Mosseri M, Fisher D, Yossipovitch O, Pisanty S, Markitziu A. Perioperative hemodynamic changes in ischemic heart disease patients undergoing dental treatment. *Spec Care Dentist* 1992; **12**: 84–8.
17. Cintron H, Medina R, Reyes AA, Lyman G. Cardiovascular effects and safety of dental anesthesia and dental interventions in patients with recent uncomplicated myocardial infarction. *Arch Intern Med* 1986; **146**: 2203–4.
18. Schoen F. The heart. In: Kumar V, ed. *Robbins and Cotran: Pathologic basis of disease*, 7th edn. St. Louis, MO: Saunders, 2005: 584–6.
19. Hwang D, Wang H-L. Medical contraindications to implant therapy, Part I: Absolute contraindications. *Implant Dent* 2006; **15**: 353–60.
20. Fatahzadeh M, Glick M. Stroke: epidemiology, classification, risk factors, complications, diagnosis, prevention, and medical and dental management. *Oral Surg Oral Med Oral Pathol Oral Radiol Endodontol* 2006; **102**: 180–91.
21. Felberg RA, Naidech AM. The 5 Ps of acute ischemic stroke treatment: parenchyma, pipes, perfusion, penumbra and prevention of complications. *South Med J* 2003; **96**: 336–42.
22. Warlow C, Sudlow C, Dennis M, Wardlow J, Sandercock P. Stroke. *Lancet* 2003; **362**: 1211–24.
23. Felberg RA, Burgin WS, Grotta JC. Neuroprotection and the ischemic cascade. *CNS Spectr* 2000; **5**: 52–8.
24. Smith WS, Hauser SL, Easton JD. Cerebrovascular diseases. In: Braunwald E, Hauser S, Fauci AS, Longo DL, Kasper DL, Jameson JL, eds. *Harrison's principles of internal medicine*, 15th edn. New York: McGraw-Hill, 2001.
25. Toole J. Vascular diseases. In: Rowland L, ed. *Merritt's textbook of neurology*. Philadelphia, PA: Lea & Febiger, 1989.
26. Kelley RE, Minagar A. Cardioembolic stroke: an update. *South Med J* 2003; **96**: 343–9.
27. Markesbery W. The central nervous system. In: Golden A, Powell DE, Jennings CD, eds. *Pathology. Understanding human disease*. Baltimore, MD: William and Wilkins, 1985.
28. Zweifler RM. Management of acute stroke. *South Med J* 2003; **96**: 354–8.
29. American Heart Association. *Targeting the facts*. Dallas, TX: AHA, 2002.
30. Gupta A, Pansari K, Shett H. Post stroke depression. *Int J Clin Pract* 2002; **56**: 531–7.
31. Little JW, Falace DA, Miller GS, Rhodus NL. Neurological disorders. In: Little JW, Falace DA, Miller GS, Rhodus NL, eds. *Dental management of the medically compromised patient*. St Louis, MO: Mosby, 2002: 417–28.
32. Ostuni E. Stroke and the dental patient. *J Am Dent Assoc* 1994; **125**: 721–7.
33. Gordon C, Langton HR, Wadw D. Dysphagia in acute stroke. *BMJ* 1987; **295**: 411–14.
34. Shapiro S, Irwin M, Hamby CL. Dysphagia and the elderly: an emerging challenge for dentistry. *J Okla Dent Assoc* 1991; **81**: 20–5.
35. Ciarrocca KN, Greenberg MS, Garfunkel A. Neuromuscular diseases. In: Greenberg M, Glick M, eds. *Burket's oral medicine diagnosis and treatment*. Hamilton, BC: Decker, 2003: 592–605.
36. Little JW, Miller CS, Henry RG, McIntosh BA. Antithrombotic agents: implications in dentistry. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2002; **93**: 544–51.
37. http://medicinenet.com
38. Rees TD, Mealey B. Periodontal treatment of the medically compromised patient. In: *Periodontics, medicine, surgery, and implants*. St Louis, MO: Mosby, 2004.
39. Dajani AS, Taubert KA, Wilson W, Balger AF, Bayer A, Ferrieri P, *et al.* Prevention of bacterial endocarditis. Recommendations by the American Heart Association. *JAMA* 1997; **277**: 1794–801.
40. Genco RJ, Grossi SG, Zambon JJ, Reynolds H, Ho A, Garrett S. Frequency of bacteremia following different modalities of periodontal treatment [abstract 842]. *J Dent Res* 2001; **80**: 141.
41. Guntheroth WG. How important are dental procedures as a cause of infective endocarditis? *Am J Cardiol* 1984; **54**: 797–801.
42. Creighton JM. Dental care for the pediatric cardiac patient. *J Can Dent Assoc* 1992; **58**: 201–7.
43. Glaser DL, Kaplan FS. Osteoporosis. Definition and clinical presentation. *Spine* 1997; **22**: 12–16S.
44. Mori H, Manabe M, Kurachi Y, Nagumo M. Osseointegration of dental implants in rabbit bone with low mineral density. *J Oral Maxillofac Surg* 1997; **55**: 351–61.
45. Heersche JN, Bellows CG, Ishida Y. The decrease in bone mass associated with aging and menopause. *J Prosthet Dent* 1998; **19**: 14–16.
46. Cann CE, Genant HK, Kolb FO, Ettinger B. Quantitative computed tomography for prediction of vertebral fracture risk. *Bone* 1985; **6**: 1–7.
47. Wakley GK, Baylink, DJ. Implants: systemic influences. *Calif Dent Assoc J* 1987; **15**: 76–85.
48. Roberts WE, Simmons KE, Garetto LP, DeCastro RA. Bone physiology and metabolism in dental implantology: risk factors for osteoporosis and other metabolic bone diseases. *Implant Dent* 1992; **1**: 11–21.
49. Dao TT, Anderson JD, Zarb GA. Is osteoporosis a risk factor for osseointegration of dental implants? *Int J Oral Maxillofac Implants* 1993; **8**: 137–44.
50. Beiker T, Flemmig T. Implants in the medically compromised patient. *Crit Rev Oral Biol Med* 2003; **14**: 305–16.
51. Sugarbaker ED. Osteitis deformans (Paget's disease of bones). *Am J Surg* 1940; **48**: 417.
52. Tiegs RD. Paget's disease of bone: indications for treatment and goals of therapy. *Clin Ther* 1997; **19**: 1309–29.
53. Sharpe PT. *Medical Intelligence Unit: The molecular biology of Paget's disease*. Georgetown, TX: RG Landes, 1996: 45.

54. Meunier PJ, Coindre JM, Edouard CM, Arlot ME. Bone histomorphometry in Paget's disease. *Arthritis Rheum* 1980; **23**: 1095–103.
55. Siris ES, Canfield RE. Paget's disease of bone. In: Becker KL, ed. *Principles and practice of endocrinology and metabolism.* Philadelphia, PA: Lippincott, 1990: 504–12.
56. Altman RD. Paget's disease of bone. In: Coe FL, Favus MJ, eds. *Disorders of bone and mineral metabolism*, 2nd edn. Philadelphia, PA: Lippincott Williams and Wilkins, 2002: 1010.
57. Cooper C, Schafheutle K, Dennison E, Kellingray S, Guyer P, Barker D. The epidemiology of Paget's disease in Britain: is the prevalence decreasing? *J Bone Miner Res* 1999; **14**: 192–7.
58. Paget J. On a form of chronic inflammation of bone (osteitis deformans). *Med Chir Trans* 1877; **60**: 37–63.
59. Sofaer JA, Holloway SM, Emery AE. A family study of Paget's disease of bone. *J Epidemiol Community Health* 1983; **37**: 226–31.
60. Siris ES, Ottman R, Flaster E, Kelsey JL. Familial aggregation of Paget's disease of bone. *J Bone Miner Res* 1991; **6**: 495–500.
61. Rebel A, Malkani K, Basle M, Bregeon C, Patezour A, Filmon R, *et al.* Particularities ultrasructuales des osteoclastes de la maladie de Paget. *Rev Rheum* 1974; **41**: 767–71.
62. Mills BG, Singer FR. Nuclear inclusions in Paget's disease of bone. *Science* 1976; **194**: 201–2.
63. Mii Y, Miyauchi Y, Honoki K, Morishita T, Miura S, Aoki M, *et al.* Electron microscopic evidence of a viral nature for osteoclast inclusions in Paget's disease of bone. *Virchows Arch* 1994; **424**: 99–104.
64. Cartwright EJ, Gordon MT, Freemont AJ, Anderson DC, Sharpe PT. Paramyxovirus and Paget's disease. *J Med Virol* 1993; **40**: 133–41.
65. Barry HC. *Paget's disease of bone*. London: E&S Livingstone, 1969: 82.
66. Dalinka MK, Aronchik JM, Haddad JG Jr. Paget's disease. *Orthop Clin North Am* 1983; **14**: 3–19.
67. Cawley MI. Complications of Paget's disease of bone. *Gerontology* 1983; **29**: 276–87.
68. Kaplan FS, Haddad JG, Singer FR. Paget's disease: complications and controversies. *Calcif Tissue Int* 1994; **55**: 75–8.
69. Smith BJ, Eveson JW. Paget's disease of bone with particular reference to dentistry. *J Oral Pathol* 1981; **10**: 233–47.
70. Altman RD, Block DA, Hochberg MC, Murphy WA. Prevalence of pelvic Paget's disease of bone in the US. *J Bone Miner Res* 2000; **15**: 461–5.
71. Albrektson T, Blomberg S, Brånemark A, Carlsson GE. Endentulousness: an oral handicap. Patient reactions for treatment with jaw bone anchored prostheses. *J Oral Rehabil* 1987; **14**: 503–11.
72. Haraldson T, Carlsson GE. Chewing efficiency in patients with osseointegrated oral implant bridges. *Swed Dent J* 1979; **3**: 183–91.
73. Sugerman PB, Barber MT. Patient selection for endosseous dental implants: oral and systemic considerations. *Int J Oral Maxillofac Implants* 2002; **17**: 191–201.
74. Tanner T. Treatment planning for dental implants: considerations, indications, and contraindications. *Dent Update* 1997; **24**: 253–60.
75. Addy L, Korszun A, Jagger RG. Dental implant treatment for patients with psychiatric disorders. *Eur J Prosthodont Restor Dent* 2006; **14**: 90–2.
76. Niessen L, Jones J. Alzheimer's disease: a guide for dental professionals. *J Spec Care Dent* 1986; **6**: 6–12.
77. State of Maryland. *Task force on Alzheimer's disease and related disorders – interim report*. Baltimore, MD: The Task Force, 1985.
78. Besdine R. Dementia. In: Besdine RW, Rowe JW, eds. *Health and disease in old age.* Boston, MA: Little, Brown & Co., 1982: 97–114.
79. Lishman WA. Alzheimer's disease. In: *Organic psychiatry*. Boston, MA: Blackwood Scientific, 1978: 540–6.
80. Besdine R, Gurian B, Terry T, Wetle T. *Handbook of geriatric care*. Hanover, NJ: Sandoz, 1982: 47–56.
81. Burnside IM. Alzheimer's disease: an overview. *J Gerontol Nurs* 1979; **5**(4): 14–20.
82. Arie T. Dementia in the elderly, diagnosis and assessment. *BMJ* 1973; **iv**: 504–43.
83. Katz S, Ford AB, Moskowitz RW, Jackson BA, Jaffe MW. Studies of illness in the aged. The index of ADL: a standardized measure of biological and psychosocial function. *JAMA* 1963; **185**: 914–19.
84. Louis ED. The shaking of palsy, the first forty-five years: a journey through the British literature. *Mov Disord* 1997; **12**: 1068–72.
85. Lord Walton of Detchant. Decade of the brain: neurological advances. *J Neurol Sci* 1998; 158: 5–14.
86. Chrischilles EA, Rubenstein LM, Voelker MD, Wallace RB, Rodnitzky RL. The health burdens of Parkinson's disease. *Mov Disord* 1998; **13**: 406–13.
87. Soykan I, Sarosiek I, Shifflett J, Wooten GF, McCollum RW. Effect of chronic oral domperidone therapy on gastrointestinal symptoms and gastric emptying in patients with Parkinson's disease. *Mov Disord* 1997; **12**: 952–7.
88. Edwards LL, Pfeiffer RF, Quigley EMM, Hofmann R, Balluff M. Gastrointestinal symptoms in Parkinson's disease. *Mov Disord* 1991; **6**: 151–6.
89. Safkan B, Knuuttila M. Corticosteroid therapy and periodontal disease. *J Clin Periodontol* 1984; **11**: 515–22.
90. Markitziu A, Zafiropoulos G, Flores de Jacoby L, Pisanty S. Periodontal alterations in patients with perphigus vulgaris taking steroids. A biannual assessment. *J Clin Periodontol* 1990; **17**: 228–32.
91. Dubois EF, Röder E, Dekhuijzen PNR, Zwinderman AE, Schweitzer DH. Dual energy X-ray absorptiometry outcomes in male COPD patients after treatment with different flucocorticoid regimens. *Chest* 2002; **121**: 1456–63.
92. Heinemann DF. Osteoporosis. An overview of the National Osteoporosis Foundation clinical practice guide. *Geriatrics* 2000; **55**: 31–6.
93. Ruggiero SL, Drew SJ. Osteonecrosis of the jaws and bisphosphonate therapy. *J Dent Res* 2007; **86**: 1013–21.
94. Marx RE. Pamidronate (Aredia) and zoledronate (Zometa) induced avascular necrosis of the jaws: a growing epidemic. *J Oral Maxillofac Surg* 2003; **61**: 1115–18.
95. Body JJ, Bartl R, Burckhardt P, Delmas PD, Diel IJ, Fleisch H, *et al.* Current use of bisphosphonates in oncology. *J Clin Oncol* 1998; **16**: 3890–9.

96. Estilo CL, Williams T, Evtimovska E, Tkach L, Halpern JL, Tunick SJ, Huryn JM. Osteonecrosis of the maxilla and mandible; possible drug-induced complication of bisphosphonate therapy. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2004; **97**: 449–50.
97. Ruggiero Sl, Mehrotra B, Rosenberg TJ, Engroff SL. Osteonecrosis of the jaws associated with the use of bisphosphonates: a review of 63 cases. *J Oral Maxillofac Surg* 2004; **62**: 527–34.
98. Wang J, Goodger NM, Pogrel MA. Osteonecrosis of the jaws associated with cancer chemotherapy. *J Oral Maxillofac Surg* 2003; **61**: 1104–7.
99. Pogrel MA. Bisphosphonates and bone necrosis. *J Oral Maxillofac Surg* 2004; **62**: 391–2.
100. Marder M. Medical conditions affecting the success of dental implants. *Compendium* 2004; **25**: 739–56.
101. Marx RE, Sawatari Y, Fortin M, Broumand V. Bisphosphonate-induced exposed bone (osteonecrosis/osteopetrosis) of the jaws: risk factors, recognition, prevention and treatment. *J Oral Maxillofac Surg* 2005; **63**: 1567–75.
102. AAOMS Position Paper. American Association of Oral and Maxillofacial Surgeons position paper on bisphosphonate related osteonecrosis of the jaws. *J Oral Maxillofac Surg* 2007; **65**: 369–76.
103. Blinder D, Manor Y, Martinowitz U, Taicher S, Haswhomer T. Dental extractions in patients maintained on continued oral anticoagulants: comparison of local hemostatic modalities. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1999; **88**: 137–40.
104. Little JW, Falace DA, Miller CS, Rhodus NL. *Dental management of the medically compromised patient*, 5th edn. St Louis, MO: CV Mosby, 1997.
105. Schardt-Sacco D. Update on coagulopathies. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2000; **90**: 559–63.
106. Brennan M, Wynn R, Miller C. Aspirin and bleeding in dentistry: an update and recommendations. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2007; **104**: 316–23.
107. Antithrombotic Trialists' Collaboration. Collaborative metanalysis of randomized trials of antiplatelet therapy for prevention of death, myocardial infarction, and stroke in high risk patients. *BMJ* 2002; **324**: 71–86.
108. Steinhubl SR. Optimizing antiplatelet therapy for the ACS patient: reacting to clinical trial data from the ISAR-REACT-2 studies. *Rev Cardiovasc Med* 2006; **7** (Suppl 4): S12–19.
109. Bhatt DL. Clopidogrel bisulfate in ST-segment elevation myocardial infarction: a viewpoint by Deepak L Bhatt. *Am J Cardiovasc Drugs* 2006; 6: 415–16.
110. Chu MW, Wilson SR, Novick RJ, Stitt LW, Quantz MA. Does clopidogrel increase blood loss following coronary artery bypass surgery? *Ann Thorac Surg* 2004; **78**: 1536–41.
111. Leong JY, Baker RA, Shah PJ, Cherian VK, Knight JL. Clopidogrel and bleeding after coronary artery bypass graft surgery. *Ann Thorac Surg* 2005; **80**: 928–33.
112. Grines CL, Bonow RO, Casey DE Jr, Gardner, TJ, Lockhart PB, Moliterno DJ, *et al.* Prevention of premature discontinuation of dual antiplatelet therapy in patients with coronary artery stents. A science advisory from the American Heart Association, American College of Cardiology, Society for Cardiovascular Angiography and Interventions, American College of Surgeons, and American Dental Association, with representation for the American College of Physicians. *Circulation* 2007; **115**: 813–18.
113. DeCaterina R, Lanza M, Manca G, Strata GB, Maffei S, Salvatore L. Bleeding time and bleeding: an analysis of the relationship of the bleeding time test with parameters of surgical bleeding. *Blood* 1994; **84**: 3363–70.
114. Ferraris VA, Swanson E. Aspirin usage and perioperative blood loss in patients undergoing unexpected operations. *Surg Gynecol Obstet* 1983; **156**: 439–42.
115. Oates T, Beirne R, Ellingsen J. Antibiotic prophylaxis for routine implant placement. *Int J Oral Maxillofac Implants* 2008; **23**: 3.
116. Mazzocchi A, Passi L, Moretti R. Retrospective analysis of 736 implants inserted without antibiotic therapy. *J Oral Maxillofac Surg* 2007; **65**: 2321–3.
117. Zarb GA, Schmitt A. Osseointegration for elderly patients: the Toronto study. *J Prosthet Dent* 1994; **72**: 559–68.
118. Roynesdal AK, Amundrud B, Hannaes HR. A comparative clinical investigation of 2 early loaded ITI dental implants supporting an overdenture in the mandible. *Int J Oral Maxillofac Implants* 2001; **16**: 246–51.
119. Mokdad AH, Bowman BA, Ford ED, Vinicor F, Marks JS, Koplan JP. The continuing epidemics of obesity and diabetes in the United States. *JAMA* 2001; **286**: 1195–200.
120. Hanlon JT, Schmader KE, Ruby CM, Weinberger M. Suboptimal prescribing in older inpatients and outpatients. *J Am Geriatr Soc* 2001; **49**: 200–9.
121. Hajjar ER, Cafiero AC, Hanlon JT. Polypharmacy in elderly patients. *Am J Geriatr Pharmacother* 2007; **5**: 345–51.
122. Mealey BL, Ocampo G. Diabetes mellitus and periodontal disease. *Periodontology 2000* 2007; **44**: 127–53.
123. Mealey BL, Oates TW. Diabetes mellitus and periodontal diseases. *J Periodontol* 2006; **77**: 1289–303.
124. Nevins ML, Karimbux NY, Weber HP, Giannobile WV, Fiorellini JP. Wound healing around endosseous implants in experimental diabetes. *Int J Oral Maxillofac Implants* 1998; **13**: 620–9.
125. Iyama S, Takeshita F, Ayukawa Y, Kido MA, Suetsugu T, Tanaka T. A study of the regional distribution of bone formed around hydroxylapatite implants in the tibiae of streptozotocin-induced diabetic rats using multiple fluorescent labeling and confocal laser scanning microscopy. *J Periodontol* 1997; **68**: 1169–75.
126. Casap N, Nimri S, Ziv E, Sela J, Samuni Y. Type 2 diabetes has minimal effect on osseointegration of titanium implants in Psammomys obesus. *Clin Oral Implant Res* 2008; **19**: 658–64.
127. Kwon PT, Rahman SS, Kim DM, Kopman JA, Karimbux NY, Fiorellini JP. Maintenance of osseointegration utilizing insulin therapy in a diabetic rat model. *J Periodontol* 2005; **76**: 621–6.
128. Klokkevold PR, Han TJ. How do smoking, diabetes and periodontitis affect outcomes of implant treatment? *Int J Oral Maxillofac Implants* 2007; **22** (Suppl): 173–98.
129. Olson JW, Shernoff AF, Tarlow JL, Colwell JA, Scheetz JP, Bingham SF. Dental endosseous implant assessments in a type 2 diabetic population: a prospective study. *Int J Oral Maxillofac Implants* 2000; **15**: 811–18.

130. Peled M, Ardekian L, Tagger-Green N, Gutmacher Z, Machtei EE. Dental implants in patients with type 2 diabetes mellitus: a clinical study. *Implant Dent* 2003; **12**: 116–22.
131. Behneke A, Behneke N, d'Hoedt B. A 5-year longitudinal study of the clinical effectiveness of ITI solid screw implants in the treatment of mandibular edentulism. *Int J Oral Maxillofac Implants* 2002; **17**: 799–810.
132. Meijer HJ, Batenburg RH, Arghoebar GM, Vissink A. Mandibular overdentures supported by two Brånemark, IMZ or ITI implants: a 5-year prospective study. *J Clin Periodontol* 2004; **31**: 522–6.
133. Morris HF, Ochi S, Winkler S. Implant survival in patients with type 2 diabetes: Placement to 36 months. *Ann Periodontol* 2000; **5**: 157–65.
134. Fiorellini JP, Chen PK, Nevins M, Nevins ML. A retrospective study of dental implants in diabetic patients. *Int J Periodontics Restorative Dent* 2000; **20**: 366–73.
135. American Diabetes Association. Standards of medical care in diabetes – 2008. *Diabetes Care* 2008; **31** (Suppl 1): s12–54.
136. Diabetes Control and Complications Trial Research Group. The effect of intensive treatment of diabetes on the development and progression of long-term complications in insulin-dependent diabetes mellitus. *N Engl J Med* 1993; **329**: 977–86.
137. UK Prospective Diabetes Study (UKPDS) Group. Intensive blood-glucose control with sulphonylureas or insulin compared with conventional treatment and risk of complications in patients with type 2 diabetes (UKPDS 33). *Lancet* 1998; **352**: 837–53.
138. Dowell S, Oates TW, Robinson M. Implant success in people with type 2 diabetes mellitus with varying glycemic control: a pilot study. *J Am Dent Assoc* 2007; **138**: 355–61.
139. Johnson GK, Guthmiller JM. The impact of cigarette smoking on periodontal disease and treatment. *Periodontol 2000* 2007; **44**: 178–94.
140. Bain CA, Moy PK. The association between the failure of dental implants and cigarette smoking. *Int J Oral Maxillofac Implants* 1993; **8**: 609–15.
141. Lambert PM, Morris HF, Ochi S. The influence of smoking on 3-year clinical success of osseointegrated dental implants. *Ann Periodontol* 2000; **5**: 79–89.
142. Hinode D, Tanabe S, Yokoyama M, Fujisawa K, Yamauchi E, Miyamoto Y. Influence of smoking on osseointegrated implant failure: a meta-analysis. *Clin Oral Implants Res* 2006; **17**: 473–8.
143. Strietzel FP, Reichart PA, Kale A, Kulkarni M, Wegner B, Kuchler I. Smoking interferes with the prognosis of dental implant treatment: a systematic review and meta-analysis. *J Clin Periodontol* 2007; **34**: 523–44.
144. Buser D, Ingimarsson S, Dula K, Lussi A, Hirt HP, Belser UC. Long-term stability of osseointegrated implants in augmented bone: a 5-year prospective study in partially edentulous patients. *Int J Periodontics Restorative Dent* 2002; **22**: 109–17.
145. Wallace SS, Froum SJ. Effect of maxillary sinus augmentation on the survival of endosseous dental implants. A systematic review. *Ann Periodontol* 2003; **8**: 328–43.
146. Esposito M, Grusovin MG, Coulthard P, Worthington HV. The efficacy of various bone augmentation procedures for dental implants: a Cochrane systematic review of randomized controlled clinical trials. *Int J Oral Maxillofac Implants* 2006; **21**: 696–710.
147. Bain CA, Weng D, Meltzer A, Kohles SS, Stach RM. A meta-analysis evaluating the risk for implant failure in patients who smoke. *Compend Contin Educ Dent* 2002; **23**: 695–704.
148. Kumar A, Jaffin RA, Berman C. The effect of smoking on achieving osseointegration of surface-modified implants: a clinical report. *Int J Oral Maxillofac Implants* 2002; **17**: 816–19.
149. Weyant RJ. Characteristics associated with the loss and peri-implant tissue health of endosseous dental implants. *Int J Oral Maxillofac Implants* 1994; **9**: 95–102.
150. Yin JT, Dobkin JF, Grbic JT. Epidemiology, pathogenesis, and management of human immunodeficiency virus infection in patients with periodontal disease. *Periodontol 2000* 2007; **44**: 55–81.
151. Achong RM, Shetty K, Arribas A, Block MS. Implants in HIV-positive patients: 3 case reports. *J Oral Maxillofac Surg* 2006; **64**: 1199–203.
152. Stevenson GC, Riano PC, Moretti AJ, Nichols CM, Engelmeier RL, Flaitz CM. Short-term success of osseointegrated dental implants in HIV-positive individuals: a prospective study. *J Contemp Dent Pract* 2007; **8**: 1–10.
153. Streitzel FP, Rothe S, Reichart PA, Schmidt-Westhausen AM. Implant-prosthetic treatment in HIV-infected patients receiving highly active antiretroviral therapy: report of cases. *Int J Oral Maxillofac Implants* 2006; **21**: 951–6.
154. Miller CS, Egan RM, Falace DA, Rayens MK, Moore CR. Prevalence of infective endocarditis in patients with systemic lupus erythematosus. *J Am Dent Assoc* 1999; **130**: 387–92.
155. Nelson K, Heberer S, Glatzer C. Survival analysis and clinical evaluation of implant-retained prostheses in oral cancer resection patients over a mean follow-up period of 10 years. *J Prosthet Dent* 2007; **98**: 405–10.
156. Kovacs AF. Clinical analysis of implant losses in oral tumor and defect patients. *Clin Oral Implants Res* 2000; **11**: 494–504.
157. Kovacs AF. Influence of chemotherapy on endosteal implant survival and success in oral cancer patients. *Int J Oral Maxillofac Surg* 2001; **30**: 144–7.
158. Barasch A, Coke JM. Cancer therapeutics: an update on its effects on oral health. *Periodontol 2000* 2007; **44**: 44–54.
159. Colella G, Cannavale R, Pentenero M, Gandolpho S. Oral implants in radiated patients: a systematic review. *Int J Oral Maxillofac Implants* 2007; **22**: 616–22.
160. Granstrom G. Osseointegration in irradiated cancer patients: an analysis with respect to implant failures. *J Oral Maxillofac Surg* 2005; **63**: 579–85.
161. Yerit KC, Posch M, Seemann M, Hainich S, Dortbudak O, Turhani D, *et al.* Implant survival in mandibles of irradiated oral cancer patients. *Clin Oral Implants Res* 2006; **17**: 337–44.
162. Schoen PJ, Raghoebar GM, Bouma J, Reintsema H, Vissink A, Sterk W, Roodenburg JL. Rehabilitation of oral function in head and neck cancer patients after radiotherapy with implant-retained dentures: effects of hyperbaric oxygen therapy. *Oral Oncol* 2007; **43**: 379–88.

163. Esposito M, Irsch J-M, Lekholm U, Thomsen P. Biological factors contributing to failures of osseointegrated oral implants. 1. Success criteria and epidemiology. *Eur J Oral Sci* 1998; **106**: 527–51.
164. Niwa H, Sato Y, Matsuura H. Safety of dental treatment in patients with previously diagnosed acute myocardial infarction or unstable angina pectoris. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2000; **89**: 35–41.
165. Roberts HW, Mitnitsky EF. Cardiac risk stratification for postmyocardial infarction dental patients. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2001; **91**: 676–81.
166. Ardekian L, Gaspar R, Peled M, Brener B, Laufer D. Does low dose aspirin therapy complicate oral surgical procedures? *J Am Dent Assoc* 2000; **131**: 331–5.
167. Johnson-Leong C, Rada RE. The use of low molecular weight heparins in outpatient oral surgery for patients receiving anticoagulation therapy. *J Am Dent Assoc* 2002; **133**: 1083–7.
168. Wahl M. Myths of dental surgery in patients receiving anticoagulant therapy. *J Am Dent Assoc* 2000; **131**: 77–81.
169. Jeske AH, Suchko GD. ADA Council on Scientific Affairs and Division of Science. Lack of a scientific basis for routine discontinuation of oral anticoagulation therapy before dental treatment. *J Am Dent Assoc* 2003; **134**: 1492–7.
170. Gage BF, Fihn SD, White RH. Warfarin therapy for an octogenarian who has atrial fibrillation. *Ann Intern Med* 2001; **134**: 465–74.
171. Wynn RL. Dental nonsteroidal anti-inflammatory drugs and prostaglandin based drug interactions, part one. *Gen Dent* 1992; **40**: 18–20.
172. Rice PJ, Perry RJ, Afzal Z, Stockley IH. Antibacterial prescribing and warfarin: a review. *Br Dent J* 2003; **194**: 411–15.
173. Searcy RL, Foreman JA, Myers HD, Bergquist LM. Anticoagulant properties of tetracyclines. *Antimicrob Agent Chemother* 1963; **161**: 471–6.
174. O'Donnell D. Antibiotic induced potentiation of oral anticoagulant agents. *Med J Aust* 1989; **150**: 163–4.
175. Dean RP, Talbert RL. Bleeding associated with concurrent warfarin and metronidazole therapy. *Drug Intell Clin Pharm* 1980; **14**: 864.
176. Rose L, Mealey B, Minsk L, Cohen DW. Dental management of patients with cardiovascular disease. *J Am Dent Assoc* 2002; **133**: 37–44S.
177. Khader RN, Rosenberg M, American Heart Association. The 2007 American Heart Association guideline for the prescription of antibiotic prophylaxis: a brief overview. *J Mass Dent Soc* 2007; **56**: 34–6.
178. Cooper LF. Systemic effectors of alveolar bone mass and implications in dental therapy. *Periodontol 2000*; **23**: 103–9.
179. Melton LJ. Epidemiology of spinal osteoporosis. *Spine* 1997; **22**: 2–11S.
180. Nasu M, Amano Y, Kurita A, Yosue T. Osseointegration in implant embedded mandible in rats fed calcium-deficient diet: a radiological study. *Oral Dis* 1998; **4**: 84–9.
181. Fujimoto T, Niimi A, Nakai H, Ueda M. Osseointegrated implants in a patient with osteoporosis: a case report. *Int J Oral Maxillofac Implants* 1996; **11**: 539–42.
182. Lugero GG, de Falco Carpalo V, Guzzo ML, Konig B, Jorgetti V. Histomorphometric evaluation of titanium implants in osteoporotic rabbits. *Implant Dent* 2000; **9**: 303–9.
183. Rasmussen J, Hopfensperger M. Placement and restoration of dental implants in a patient with Paget's disease in remission: literature review and clinical report. *J Prosthodont* 2008; 17: 35–40.
184. Jaffin RA, Berman CL. The excessive loss of Brånemark fixtures in type IV bone: a 5 year analysis. *J Periodont* 1991; **62**: 2–4.
185. Munshi NC, Barlogie B, Desikan KR, Wilson C. Novel approaches in myeloma therapy. *Semin Oncol* 1999; **26**: 28–34.
186. Purcell PM, Boyd IW. Bisphosphonates and osteonecrosis of the jaw. *Med J Aust* 2005; **182**: 417–18.
187. Enoch MD, Jagger RG. *Psychiatric disorders in dental practice.* Oxford: Butterworth Heinemann, 1994: 119–20.
188. Welsh G, Grey N, Potts S. The use of liaison psychiatry service in restorative dentistry. *CPD Dent* 2000; **1**: 32–4.
189. Fox PC, van der Ven PF, Sonies BC, Weiffenback JM, Baum BJ. Xerostomia: evaluation of a symptom with increasing significance. *J Am Dent Assoc* 1985; **110**: 519–25.
190. Buser D, Weber HP, Lang NP. Tissue integration of non-submerged implants, 1 year results of a prospective study with 100 ITI hollow-screw and hollow-cylinder implants. *Clin Oral Implants Res* 1990; **1**: 33–40.
191. Buser D, Mericske-Stern R, Bernard JP, Behneke A, Behneke N, Hirt HP, *et al.* Long term evaluation of non submerged ITI implants. Part 1: 8 year life table analysis of progressive multi center study with 2359 implants. *Clin Oral Implants Res* 1997; **8**: 161–72.
192. Heckmann SM, Heckmann JG, Weber HP. Clinical outcomes of three Parkinson's disease patients treated with mandibular implant overdentures. *Clin Oral Implants Res* 2000; **11**: 566–7.
193. Scully C, Diz Dios P, Jumar N. *Special care in dentistry: handbook of oral healthcare.* Edinburgh: Churchill Livingstone/Elsevier, 2007.
194. Scully C, Cawson R. *Medical problems in dentistry*, 5th edn. Oxford: Churchill Livingstone, 2004.
195. Nicholson G, Burrin JM, Hall GM. Peri operative steroid supplementation. *Anaesthesia* 1998; **53**: 1091–104.
196. Thomason JM, Girdler NM, Kendall-Taylor P, Wastell H, Weddel A, Seymour RA. An investigation into the need for supplementary steroids in organ transplant patients undergoing gingival surgery. A double blind, split mouth, cross over study. *J Clin Periodontol* 1999; **26**: 577–82.
197. Medicines Control Agency: http://www.mca.gov.uk/ourwork/monirorsafequalmed/currentproblems/volume-14may.htm
198. Steiner M, Ramp WK. Endosseous dental implants and the glucocorticoid dependent patient. *J Oral Implantol* 1990; **16**: 211–17.
199. Ruggerio S, Gralow J, Marx RE, Hoff AO, Schubert MM, Huryn JM, *et al.* Practical guidelines for the prevention, diagnosis and treatment of osteonecrosis of the jaw in patients with cancer. *J Oncol Pract* 2006; **2**: 7–14.
200. Nase JB, Suzuki JB. Osteonecrosis of the jaw and oral bisphosphonate treatment. *J Am Dent Assoc* 2006; **137**: 1115–19.

201. Beauchamp J, Caufield PW, Crall JJ, Donly K, Feigal R, *et al.*; American Dental Association Council on Scientific Affairs. Evidence-based clinical recommendations for the use of pit-and-fissure sealants: a report of the American Dental Association Council on Scientific Affairs. *J Am Dent Assoc* 2008; **139**: 257–68.
202. Scully C, Wolff A. Oral surgery in patients on anticoagulant therapy. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2002; **94**: 57–64.
203. Scully C, Cawson RA. *Medical problems in dentistry*, 4th edn. Oxford: Butterworth-Heinemann, 1997.
204. Diabetes Control and Complications Trial Research Group. Hypoglycemia in the Diabetes Control and Complications Trial. *Diabetes* 1997; **46**: 271–86.
205. Action to Control Cardiovascular Risk in Diabetes (ACCORD) Study Group. Effects of intensive glucose lowering in type 2 diabetes. *N Engl J Med* 2008; **358**: 2545–59.
206. Mealey BL. Managing patients with diabetes: first, do no harm. *J Periodontol* 2007; **78**: 2072–6.
207. Bain CA. Smoking and implant failure. Benefits of a smoking cessation protocol. *Int J Oral Maxillofac Implants* 1996; **11**: 756–9.
208. Glick M, Abel SN, Muzyka BC, DeLorenzo, M. Dental complications after treating patients with AIDS. *J Am Dent Assoc* 1994; **125**: 296–301.
209. Powell CA, Mealey BL, Deas DE, McDonnell HT, Moritz AJ. Post-surgical infections: prevalence associated with various periodontal surgical procedures. *J Periodontol* 2005; **76**: 329–33.
210. Porter SR, Scully C, Luker J. Complications of dental surgery in persons with HIV disease. *Oral Surg Oral Med Oral Pathol* 1993; **75**: 165–7.
211. Robinson PG, Cooper H, Hatt J. Healing after dental extraction in men with HIV infection. *Oral Surg Oral Med Oral Pathol* 1992; **74**: 426–30.
212. Dodson TB, Perrott DH, Gongloff RK, Kaban LB. Human immunodeficiency virus serostatus and the risk of postextraction complications. *Int J Oral Maxillofac Surg* 1994; **23**: 100–3.
213. Horberg MA, Hurley LB, Klein DB, Follansbee SE, Quesenberry C, Flamm JA, *et al.* Surgical outcomes in human immunodeficiency virus-infected patients in the era of highly active antiretroviral therapy. *Arch Surg* 2006; **141**: 1238–45.
214. Holmstrup P, Glick M. Treatment of periodontal disease in the immunodeficient patient. *Periodontol 2000* 2002; **28**: 190–205.
215. Mealey BL. Periodontal implications: medically compromised patients. *Ann Periodontol* 1996; **1**: 256–321.
216. Rees TD. Periodontal management of the patient with cardiovascular disease. Position paper, American Academy of Periodontology. *J Periodontol* 2002; **73**: 954–68.
217. Cobb LA, Fahrenbruch CE, Walsh TR, Copass MK, Olsufka M, Breskin M, *et al.* Influence of cardiopulmonary resuscitation prior to defibrillation in patients with out of hospital ventricular fibrillation. *JAMA* 1999; **281**: 182–8.
218. Helm-Estrabrook N, Albert M, eds. *A manual for aphasic therapy*. Austin, TX: Pro-Ed, 1991: 159.
219. Misch CE. *Contemporary implant dentistry*, 2nd edn. St Louis, MO: Mosby, 1999: 61.
220. Kapust LR. Living with dementia: the ongoing funeral. *Social Work Health Care* 1982; **7**(4): 79–91.
221. Lind LJ, Mushlin PS, Schnitman PA. Monitored anesthesia care for dental implant surgery: analysis of effectiveness and complications. *J Oral Implantol* 1990; **16**: 106–13.
222. Zacharias M, Hunter KM, Luyk NJ. Patient controlled sedation using midazolam. *Br J Oral Maxillofac Surg* 1994; **32**: 168–73.
223. Runes J, Strom C. Midazolam intravenous conscious sedation in oral surgery. A retrospective study of 372 cases. *Swed Dent J* 1996; **20**: 29–33.
224. Craig DC, Boyle CA, Fleming GJ, Palmer P. A sedation technique for implant and periodontal surgery. *J Clin Periodontol* 2000; **27**: 955–959.
225. Dionne RA, Yagiela JA, Moore PA, Gonty A, Zuniga J, Beirne OR. Comparison efficacy and safety of four intravenous sedation regimens in dental outpatients. *J Am Dent Assoc* 2001; **132**: 740–51.
226. Mealey B, Rees T, Rose L, Grossi S. Systemic factors impacting the periodontium. In: *Periodontics, medicine, surgery and implants*. St Louis, MO: Mosby, 2004: 802–4.
227. Valerin MA, Brennan MT, Noll JL, Napenas JJ, Kent ML, Fox PC, *et al.* Relationship between aspirin use and postoperative bleeding from dental extractions in a healthy population [abstract]. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2006; **102**: 326.
228. Madan GA, Madan SG, Madan G, Madan AD. Minor oral surgery without stopping daily low dose aspirin therapy: a study of 51 patients. *J Oral Maxillofac Surg* 2005; **63**: 1262–6.
229. Garfunkel AA, Haze C, Eldor A. A suggested protocol for oral surgery patients on anticoagulant medications. *J Isr Dent Assoc* 2000; **17**: 22–3.
230. DDAVP in haemophilia and von Willebrand's disease [editorial]. *Lancet* 1983; **ii**: 774–5.
231. Dent CD, Olson JW, Farish SE, Bellome J, Casino AJ, Morris HF, Ochi S. The influence of preoperative antibiotics on success of endosseous implants up to and including stage II surgery. A study of 2,641 implants. *J Oral Maxillofac Surg* 1997; **55**: (12 Suppl 5): 19–24.
232. Sennerby L, Roos J. Surgical determinants of clinical success of osseointegrated implants: a review of the literature. *Int J Prosthodont* 1998; **11**: 408–20.
233. Wagenberg B, Froum SJ. A retrospective study of 1925 consecutively placed immediate implants from 1988–2004. *Int J Oral Maxillofac Implants* 2006; **21**: 71–80.
234. Laskin DM, Dent CD, Morris HF, Ochi S, Olson JW. The influence of preoperative antibiotics on success of endosseous implants at 36 months. *Ann Periodontol* 2000; **5**: 166–74.
235. Hunter SE, Scher RL. Clinical implications of radionecrosis to the head and neck surgeon. *Curr Opin Otolaryngol Head Neck Surg* 2003; **11**: 103–6.
236. Bennett MH, Feldmeier J, Hampson N, Smee R, Milross C. Hyperbaric oxygen therapy for late radiation tissue injury. *Cochrane Database Syst Rev* 2005 (Issue 3). Art. No.: CD005005. DOI: 10.1002/14651858.CD005005.pub2

Chapter 3

Complications associated with implant planning: etiology, prevention, and treatment

Nicolas Elian DDS, Brian Ehrlich DDS, and Geon U. Kim DDS, MS

Diagnosis and treatment planning

The introduction of osseointegrated dental implants as a restorative option in the treatment of fully and partially edentulous patients has proven to be a highly successful means of dental rehabilitation. A high survival rate of implant-supported restorations has been documented for single, multiple and full arch restorations (1–3). However, as with any treatment modality complications will occur. These complications may vary from minor (loose screw, chipped porcelain, peri-implant gingival inflammation) to major (implant failure, implant fracture, permanent nerve damage, bone necrosis) (4–10). In determining the etiology, prevention and treatment of complications, it is prudent first to evaluate whether the complications are related to inaccuracies in diagnosis and treatment planning. Owing to the significant amount of knowledge and experience that must be incorporated by practitioners who provide dental implant therapy, it follows that a primary factor responsible for complications and failures is often related to misdiagnosis and inadequate treatment planning.

This chapter will evaluate the essential parameters necessary for the diagnosis, treatment planning, and integration of implant restorations in order to achieve successful rehabilitation of patients and avoid treatment complications. Achieving these results is dependent upon understanding and identifying the factors that can cause complications and diagnosing them before treatment. Fortunately, as our knowledge and skill levels have developed, our ability has improved at perceiving potential risk factors that may cause treatment complications and failures. The examples provided in this chapter will describe the proper sequence of diagnosis and treatment planning, which when combined with proper surgical and restorative therapy may avoid many of the complications seen with implant therapy today.

Diagnosis

Know your patient

Providing successful implant treatment starts no differently than other dental procedures performed daily on patients. Initially, it is essential to obtain a thorough medical and dental history to determine whether there are any conditions that may increase the risk of potential complications. Implant treatment can involve numerous and often lengthy treatments that may span a substantially long period. Similar to situations faced in difficult prosthetic cases, treatment success can be affected by the desires, expectations, compliance, and overall personality of the patient being treated. Financial limitations may also dictate compromises in treatment planning options.

The patient interview provides the starting point in the diagnostic phase. It is important during the examination process to obtain an understanding of the patient's motivational factors and comprehension regarding treatment. The interview helps identify many important determinants that affect the development of a treatment plan. Are the patient's expectations and desires realistic? Does the patient have the temperament and physical health to tolerate the treatment modalities required? Are the patient's finances and expectations in harmony? Are there any limitations to treatment? If any of these questions generate a potential issue concerning the success of treatment, it is important to investigate the problem further. With this information, the clinician can assess the amount of risk that is associated with various potential treatment plans, and discuss these with the patient. The diagnostic phase thus provides an excellent source of information and guidance in preventing potential complications during and after treatment.

Systemic considerations

The medical concerns in implant dentistry are similar to those for other dental surgical procedures. Systemic conditions that could lead to serious morbidity and mortality problems must be known and evaluated before treatment. Any condition that could compromise the health of a patient must be identified before initiating therapy and should be discussed in detail with the patient and, when necessary, with the patient's physician. Some of the medical issues that should be evaluated include cardiovascular problems, diabetes, osteoporosis, high blood

pressure, poorly controlled metabolic conditions, bleeding problems, and medications being taken. These conditions and medications taken for their treatment could lead to an intraoperative medical crisis requiring acute emergency care. In addition, any of these medical conditions can lead to poor or delayed postsurgical healing and complications during treatment (11, 12) (see Chapter 2).

The implant treatment plan may be modified based on identified systemic conditions or in response to the medications being taken. A consultation with the patient's physician is advisable to clarify the level of risk the patient may experience during or following implant surgery. For example, patients taking anticlotting medications [i.e. aspirin, clopidogrel (Plavix) or warfarin (Coumadin)] should be evaluated for potential bleeding complications (13–15). Depending on the physician's advice and the patient's condition, a determination should be made before surgery whether or not temporarily to discontinue these medications. There are published data supporting both approaches (16–18). When the underlying systemic risk to the patient is determined to be high, a critical decision must be made. Either continue the implant treatment plan with close cooperation as needed with the patient's physician, or provide a modified treatment plan that may not include implants. In cases where implant surgery poses a high risk, a restorative plan that does not include implants may be the best option to avoid complications and failures. For example, a patient with a history of oral cancer treatment including radiation exposure to a potential implant site would not be a good candidate for implant surgery owing to the high risk for osteoradionecrosis (19).

Osteoporosis is another example of a condition that should be addressed when evaluating a potential implant patient. Osteoporosis, which is a common condition in postmenopausal women, affects bone density (20). Decreased bone density can cause a lack of primary implant stability upon placement (21, 22). When an implant is unstable at the time of placement or is placed in poor-quality bone it has an increased risk of failure to integrate. This instability may be noticed at the time of implant placement surgery and should result in aborting placement. However, it may occur at the second stage uncovering of the implant, or at a later date after placing the implant under occlusal load (23, 24). Clarifying potential bone density issues before treatment may allow a more accurate determination of the relative level of risk. For example, in areas of the mouth with poor-quality bone (i.e. the posterior maxilla), a decrease in bone density caused by osteoporosis may preclude the use of implants because of the increased risk of failure to achieve stability (4, 21, 25). Methods to improve stability in this bone include use of osteotomes for site preparation, under preparation of the site, and use of an implant with a flared platform (26–28).

Medications

During the interview phase all medications that the patient is taking should be recorded and evaluated with emphasis on how they might affect implant surgery. For example, patients with osteoporosis are often prescribed medications classified as bisphosphonates which reduce osteoclastic activity (29).

These medications have names such as ibandronate (Boniva), alendronate (Fosomax), and risedronate (Actonel). The problem that has been associated with this medication is its link to bisphosphonate-related osteonecrosis of the jaw (BRONJ) (30–32). This bone necrosis and delayed healing may manifest itself following surgical procedures which include tooth extraction, implant placement, bone augmentation, or other surgeries that affect the bone (33–35). The risk of osteonecrosis in patients taking the oral dosing is very low; however, the risk increases in patients who are taking the medication intravenously. Currently, the guidelines for treating patients on oral dosing are vague, but since there is relatively low risk the overall consensus is to treat patients without any change in surgical protocol. The clinician, however, may want to start with a less extensive surgery to "test" the healing. Patients and their physicians should be made aware of the potential risk that exists with bisphosphonates. A discussion with the patient's physician may conclude that before the surgical and healing phase a drug holiday is warranted, in which the patient will stop taking the medication for a period of time (see Chapter 2).

Deleterious drug interactions can also be avoided if a thorough medical history is obtained. For example, warfarin (Coumadin) interferes with acetaminophen (Tylenol), aspirin, erythromycin, fluconazole, and beta-blockers. Patients on atenolol (Tenormin) must avoid pseudoephedrine (Sudafed). Men taking erectile dysfunction medications, e.g. sildenafil (Viagra) or tadalafil (Cialis), should avoid nitrates (e.g. nitroglycerine). These and other drug interactions need to be avoided to reduce complications for the patient. Often patients take herbs or other over-the-counter medications, which can also cause drug interactions or affect the patient's condition, such as difficulty with clotting. Patients taking anticoagulants should avoid over-the-counter herbs such as St John's wort and gingko biloba, which in combination with the former drugs can increase the risks of spontaneous or excessive bleeding.

History concerning any allergies that affect the patient must also be elicited before treatment. Allergies to latex, anesthetics, antibiotics, and medications are quite common (36, 37). Avoiding these products and medica-

tions will minimize potential complications throughout treatment.

Social factors

The patient's habits (e.g. smoking, parafunction, recreational drugs), compliance with instructions, homecare, and psychologic issues should be assessed following the patient interview.

An example of a habit that can adversely affect the outcome of implant treatment is smoking. It has been shown that patients that smoke cigarettes are at an increased risk for complications and failure (2, 38–43). Complications and failures may become even more evident for a patient who is a smoker if additional treatments such as bone grafts or soft-tissue grafts are necessary adjunctive treatments for implant placement (44). The risk associated with smokers should be evaluated and considered as it relates to the size and scope of the planned treatment. Discussion with the patient should allow for an informed evaluation of the concerns raised.

If possible, the patient should be placed on a smoking cessation program. It has been documented that cessation of smoking one week before and three weeks after surgery will decrease the risk of implant failure (45). Patients should be made aware that healing is impaired and failure rates are higher for those who smoke cigarettes (38, 41, 46) (see Chapter 2).

Patients with parafunctional habits (e.g. bruxing, clenching) should be evaluated, counseled, and treated (occlusal guard fabrication) before implant placement, otherwise the treatment may fail (Fig. 3.1a–d).

Dental history

The patient's dental history should also be elicited. A history of surgical complications is a warning that the patient may have unknown medical problems. A history of frequent dental infections or previous implant failure should alert the clinician that a thorough medical examination and blood work-up may be necessary before treatment planning begins. In addition, it is extremely helpful in treatment planning to understand a patient's

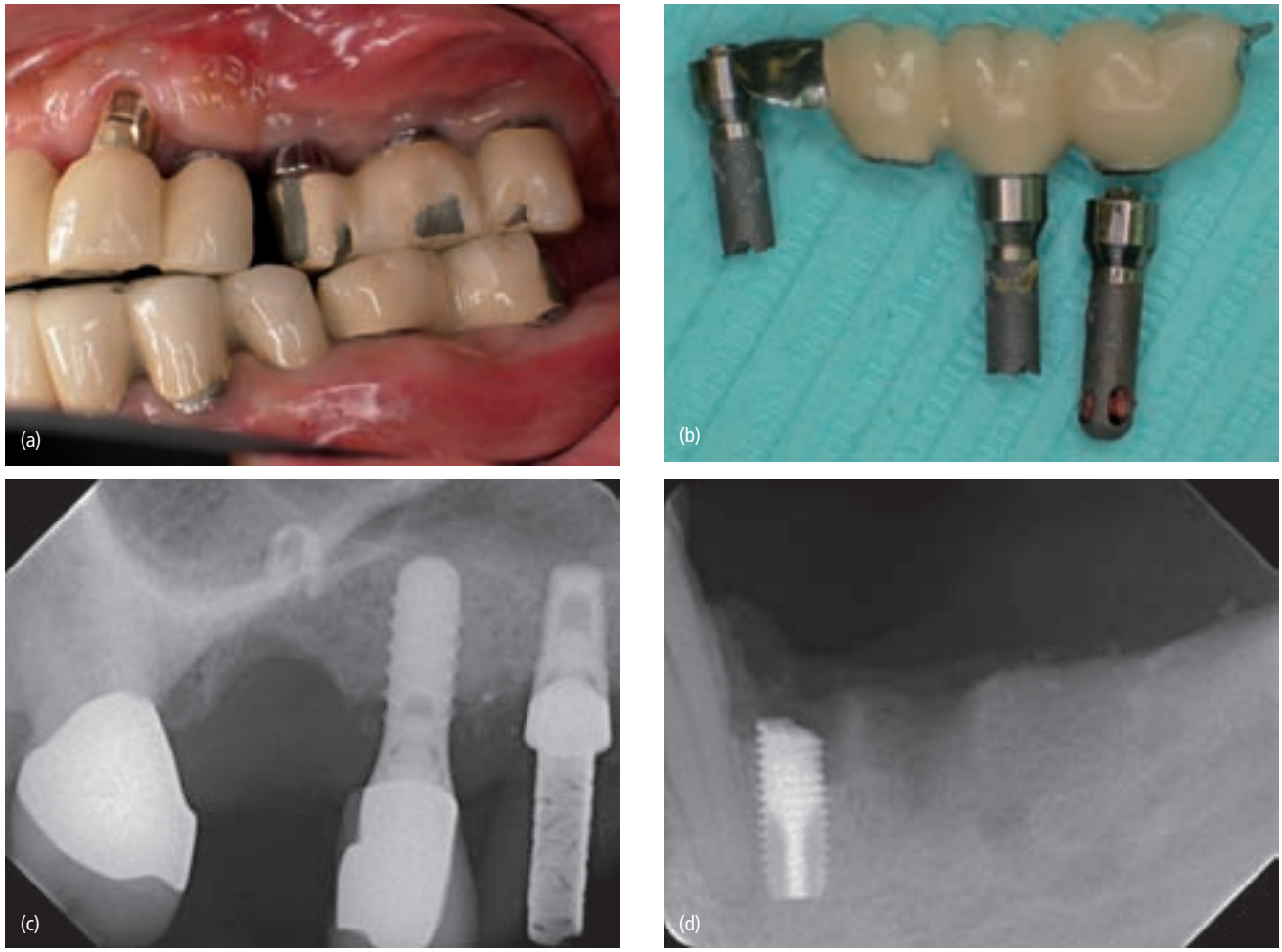


Fig. 3.1 (a) Implant-supported porcelain crown fractures due to parafunctional habits; (b) occlusal stress causing implant body fracture; (c, d) radiographs of fractured implants.

dental history. Did the patient lose their teeth owing to caries, trauma, or periodontal disease? Did the patient require any apicoectomies? What is the patient's dental IQ? Do they exhibit good homecare? What is their history regarding regular dental hygiene appointments? The answer to these and other questions can prove invaluable in determining the proper treatment plan for the patient. For example, if a patient has poor oral hygiene and does not schedule regular hygiene appointments, the patient may be at increased risk for implant failure, peri-implantitis, or an unacceptable final esthetic result (Fig. 3.2). Does a patient have sufficient bone for implant placement in an area that has had a past apicoectomy performed, or should the practitioner consider the need for bone grafting? What type of occlusion does the patient have, or did they have before losing their teeth? Is there a malocclusion, and how will it potentially affect implant placement or restorative options? These questions need to be asked and answered during the diagnostic phase of therapy. Analyzing the answers to these questions will allow treatment options to be formulated that can best avoid complications and failures.

Top–down planning

Top–down planning refers to determining the restorative treatment plan and considering all treatment options before developing the necessary surgical treatments. In this way the treatment plan will be developed with the final goal in mind. Lapses in either the restorative or surgical planning can result in failures and complications (3, 47). When considering the prospective implant site, it should be evaluated as if it were a tooth receiving a conventional fixed restoration. Implant restorations follow similar guidelines to those used with basic tooth-borne restorative dentistry. The first step is to evaluate the site for a new restoration. Is there adequate occlusal clearance? Case failure can occur if there is undiagnosed limited interarch space. In severe cases there may be no room for the placement of any prosthesis on the implant. There must be enough height for the implant abutment to provide adequate retention of the crown and for the restorative material of the crown (Fig. 3.3a, b) (48, 49) (see Chapter 9). Decisions regarding the extent of prosthetic treatment need to be made. Is a single implant-supported crown the best restorative plan? If adjacent teeth have pathology, advanced periodontal disease, or caries, it could change the preferred restorative treatment plan. Comprehensive oral examinations provide the information necessary for determining the ideal treatment plan and alternate options (see Chapter 9).

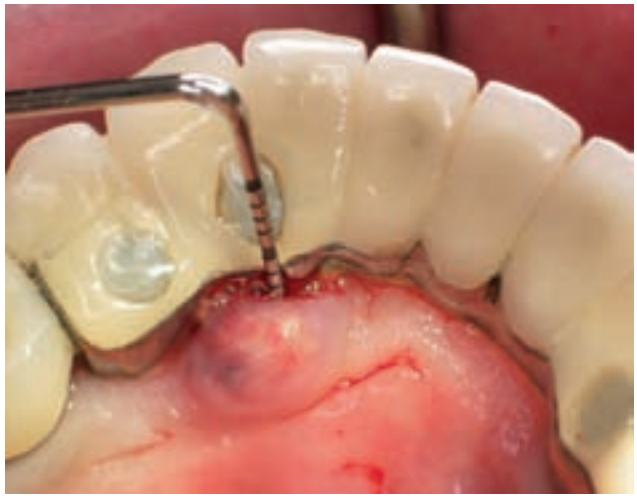


Fig. 3.2 Poor oral hygiene-related peri-implantitis.

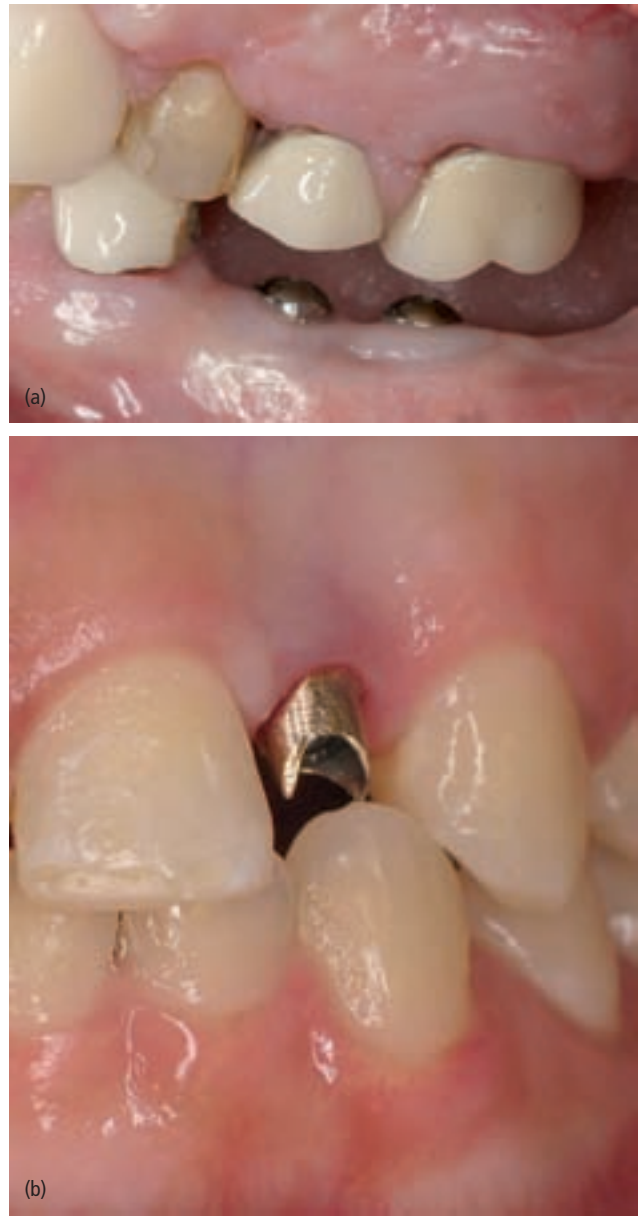


Fig. 3.3 (a) Limited interarch space posteriorly; (b) limited anterior interarch space anterior.

Avoiding and reducing the incidence of implant complications or failures is achieved by understanding the unique restorative requirements of implants. For example, how do you determine the number of implants required to restore three adjacent missing teeth, a quadrant, or a full arch? Using too few implants (underengineered) can lead to occlusal overload and ultimate failure of the prosthesis (50, 51). Using too many implants may limit interimplant space and result in difficulties with esthetics, homecare, and access to the interimplant areas. What affect does occlusion play in determining the restorative options and the number of implants to use? In considering the answer to these questions the criteria used in conventional fixed prosthetics may be used as a guide. The main difference is that the expected occlusal forces will be transmitted to implants rather than teeth. When using implants the restorative plan is dependent on the viability of getting implants to osseointegrate into the locations necessary to create the underlying support.

Spacing is another important aspect to implant success. How much space mesial to distal is required for an implant to function and provide a long-lasting and at times critically important esthetic outcome? For a single unit implant restoration there is a minimum prosthetic space required mesiodistally. If this space is not present it may not be possible to place a restoration in the site. The combined diameter of a standard implant platform, 4.0 mm, plus the amount of restorative material for the crown, usually requires a minimum 6.5–7.0 mm of mesial–distal space (Fig. 3.4) (52, 53). However, this requirement can be reduced to approximately 4.0 mm when using a narrower diameter implant or a one-piece narrow-diameter implant (54, 55).

The practitioner should also evaluate whether the planned implants will provide enough osseointegrated surface area to support the expected occlusal load, or whether a tooth-supported fixed restoration should be the treatment of choice. There is often limited evidence-based literature available to answer or define what exactly is needed for each particular restorative situation. More often, experience, training, and team planning provide the elements necessary to identify what is required.

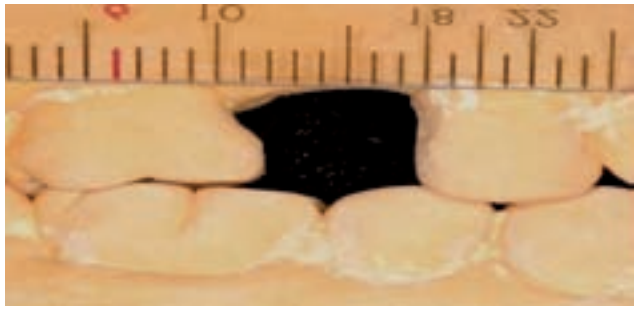


Fig. 3.4 Mesiodistal implant space requirement for a 4 mm diameter implant.

Another factor to consider with fixed restorations is whether the final restoration is to be cemented or screw retained. Esthetic requirements play a major role in deciding the size and position of the implant (see Chapters 8, 9, 11, and 12). An ideal work-up of the final prosthesis from study models is essential in planning the location, angulation, and size of the implant. Once this decision is made it can be determined whether to use a screw- or cement-retained restoration.

A cemented restoration is ideal for esthetics since it will not show any access hole for the abutment screw. This is preferred by most patients, especially in any esthetic areas. Once the abutment is screwed into place, the final crown is cemented down upon it. Provisional restorations can also be temporarily cemented on the final abutments and be used to analyze the esthetics. A problem with cemented restorations is residual cement removal. If the final crown margin has been placed too far subgingivally, it can become difficult to remove excess cement, which can lead to inflammation or peri-implantitis (56, 57). Moreover, the crown occasionally does not have adequate retention on the abutment, leading to the crown coming off, especially if temporary cement is used. If final cement is used to adhere the crown to the abutment this can potentially pose a problem should the abutment screw come loose or fracture in the future. The cemented crown may have to be cut off to gain access to the abutment screw.

Screw-retained crowns are not as esthetically pleasing to patients as cemented ones. They have an access hole that shows delineation with the porcelain (Fig. 3.5). They cannot be used in the anterior area if the implant has been overangulated towards the facial. However, they do not have margins that can introduce cement into the implant sulcus. Moreover, they are retrievable should the prosthesis require future removal. Retrievability increases in importance as a case becomes more complex or involves more implants. In addition, because there is no cement interface required to retain a crown, a screw-

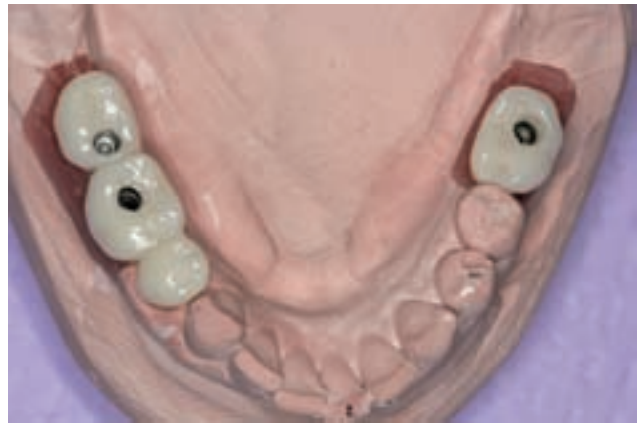


Fig. 3.5 Screw-retained access hole.

retained crown can be used when interarch occlusal space is limited (Fig. 3.6). The crown and the abutment are one component and it is the screw that attaches the crown to the implant. During the planning phase decisions need to be made as to whether a cement- or screw-retained prosthesis will better serve the patient.

Removable prostheses gain tissue support and therefore do not require the same implant support as fixed restorations (58, 59). Before surgery, decisions must be made as to the number and position of implants required. For example, for an implant-supported removable prosthesis, how many implants are required? How does a maxillary or mandibular removable prosthesis affect the position and number of implants placed? Which attachment mechanism would be best to use for long-term success? The answers to these questions have been addressed in the literature and success with removable implant-supported prostheses has been very good (60, 61). The exact number of implants needed depends on the quality of bone present and the anterior–posterior spread of the implants in the arch in relation to the size of the prosthesis (see Chapter 9).

Mandibular implant-supported dentures can be successful with as few as two implants (62, 63). This is because the anterior mandible has type I bone with a thick cortical plate. However, the maxilla often has type III or type IV bone with a thin cortical plate. Implants placed in this type of bone cannot withstand the forces generated on them as well as those in the mandible. Two implants placed in the maxilla to support a full upper denture are often not sufficient for prosthetic survival. Additional implants are usually required. Four to six implants provide a better framework for support in the maxilla (64–66). If occlusal space is available, constructing a bar to connect the implants can also alleviate lateral forces from the implants to help improve longevity (Fig. 3.7) (67). The implant treatment plan must consider these options in order to reduce the risk of failure of the implants and the prosthesis.

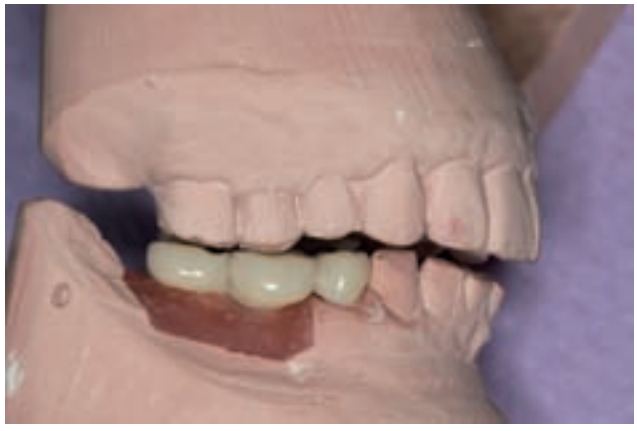


Fig. 3.6 Screw-retained restoration for limited interarch occlusal space.

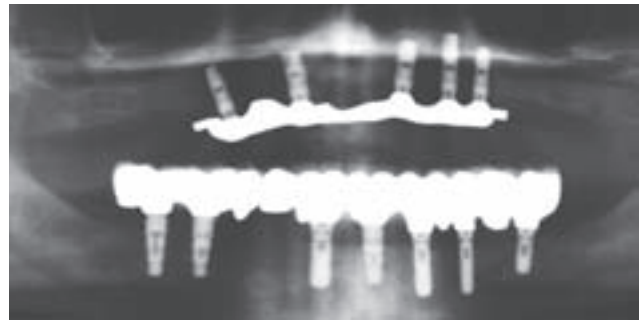


Fig. 3.7 Maxillary implants connected with a bar.

Surgical planning for implant positioning should be preceded by completely analyzing restorative options and their respective requirements. It is imperative to determine the outcome desired during surgical treatment planning (Fig. 3.8a–d). The answers obtained to the questions explored during the restorative planning phase should be communicated to the surgeon who is placing the implants, if it is not the same practitioner. These decisions will provide guidance on the number of implants to place and in which positions. They will help establish how crucial implant position and angulation are to the final restoration. One of the ways that this information can be conveyed to the implant surgeon and incorporated into the surgery is by using a surgical template fabricated from an ideal wax-up (see Chapter 4). Complications can be avoided if an accurate template is used during implant placement. An example is the complication caused when implants are placed too close together, which may create an unrestorable situation due to mesial–distal space limitations (Fig. 3.9). One or more of the implants may have to be left unrestored or the implants may need to be explanted. If implants are poorly positioned or angled, this can also create a situation that is unrestorable or unesthetic. Proper planning and guidance for implant positioning will reduce these potential complications.

Surgical planning related to the etiology of complications

An essential part of the surgical planning phase is performed in conjunction with a radiographic examination. Radiographs are essential in determining the volume, contours, position, and density of the surgical site. The diagnostic value of the radiographs depends on their clarity and the elements that they are designed to display. Periapical and panoramic radiographs are most commonly used in treatment planning. It is vital to appreciate the diagnostic quality and limitations that each of these exhibit. A periapical radiograph may not fully exhibit adjacent structures to permit proper diagnosis of potential complications, such as an adjacent root

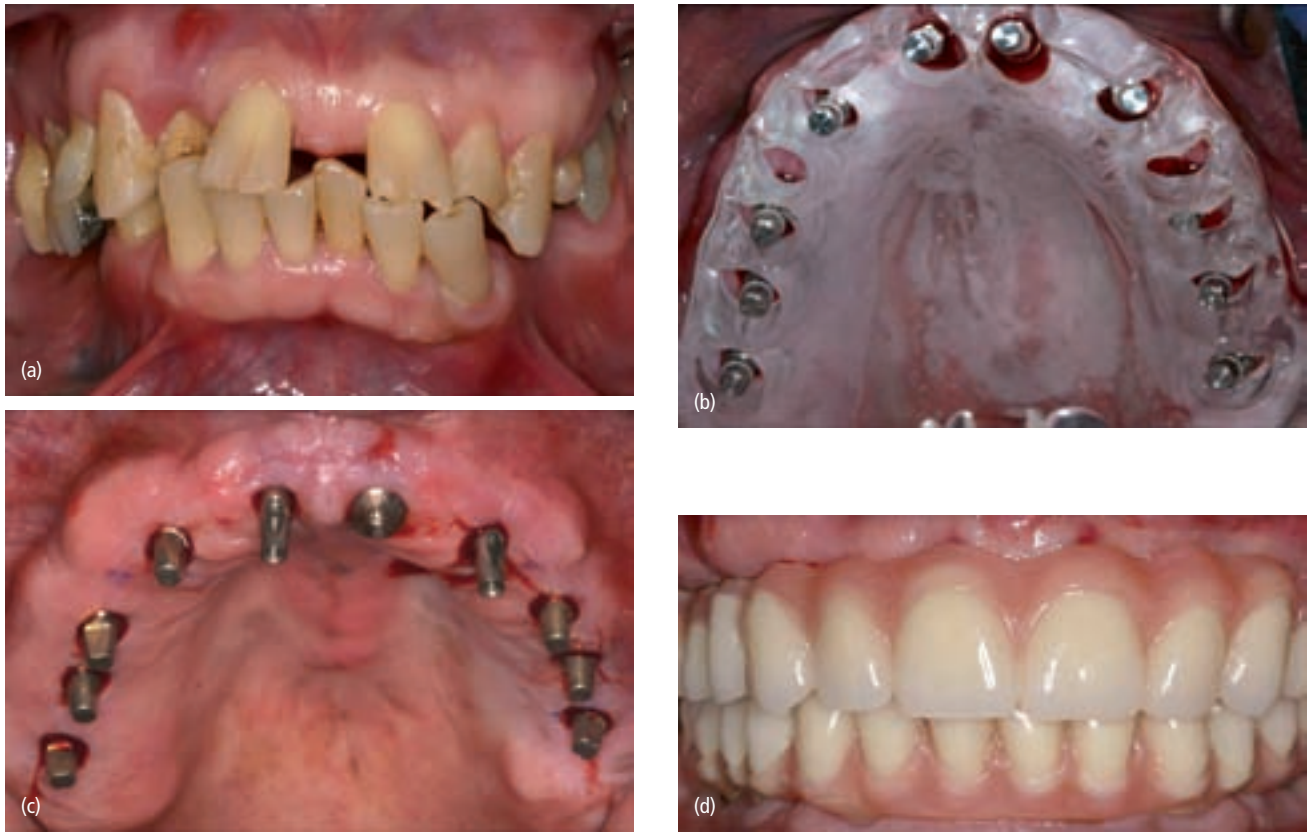


Fig. 3.8 (a) Initial case presentation before extraction of all maxillary hopeless teeth; (b) surgical guide with implants positioned according to treatment plan; (c) restorative abutment placement; (d) provisional prosthesis with ideal occlusal plane.

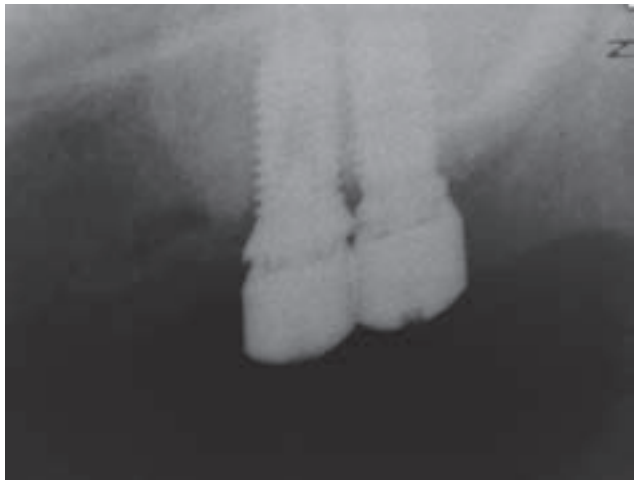


Fig. 3.9 Implants too close mesiodistally.

with periapical pathology. Panoramic radiographs, while exhibiting a comprehensive view, lack the clarity demonstrated by periapicals (Fig. 3.10a, b). The panoramic radiographs may also be distorted and display up to a 25% magnified view, and owing to a diminished clarity may cause misdiagnosis from the inability to visualize structures clearly (68, 69). Attention to these differences during the surgical planning phase is a key factor in eliminating potential complications and failures once treatment is initiated (see Chapter 4).

One of the most critical steps in the surgical planning phase is a comprehensive evaluation of the local anatomy before treatment. Surgical implant failures and complications can arise from overlooking a relevant pre-existing anatomic condition. Tooth or root proximity to a planned implant site can lead to damage by the drill or implant to the adjacent tooth, causing the affected tooth to require root canal treatment or extraction. Likewise, an adjacent tooth with an undiagnosed periapical lesion could lead to implant failure, when the infection spreads and reaches the implant surface (10, 70, 71) (see Chapter 22). Implant fenestration or dehiscence may occur on the buccal or lingual surface if the ridge lacks sufficient width (Fig. 3.11). This complication can occur during implant placement or may result after bone remodeling and loading, and can lead to a delayed functional or esthetic failure.

Another factor of prime importance concerns vital anatomic structures. Structures of importance to note before beginning treatment are the proximity of the inferior alveolar canal, mental foramen, sinus, nasal floor, and incisive canal (Fig. 3.12). In, addition, it is extremely important to understand the morphology of the surgical site. Anatomic variations can lead to perforations of the

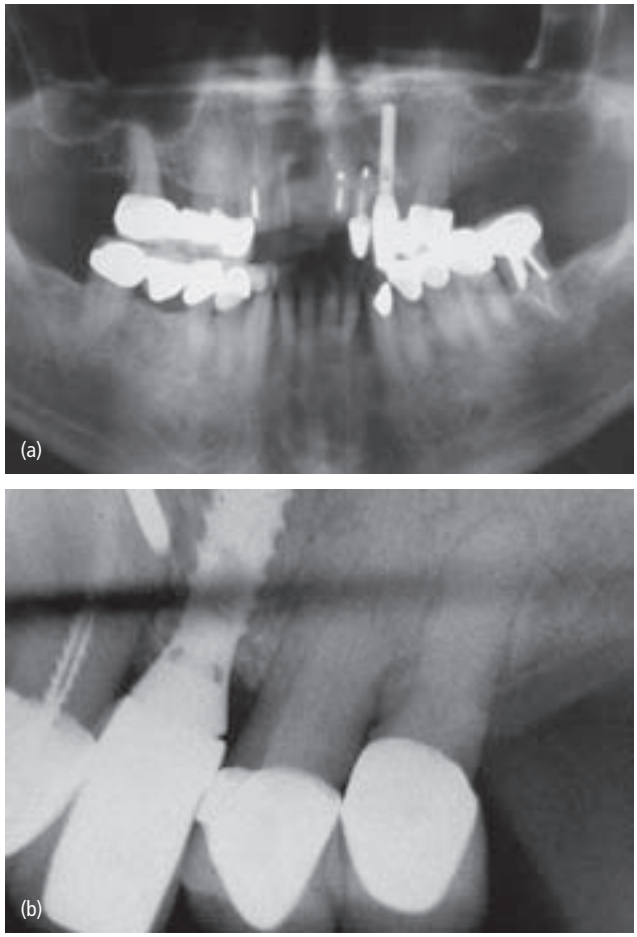


Fig. 3.10 (a) Panoramic radiograph with limited diagnostic clarity of tooth 12; (b) periapical displays improved diagnostic clarity of tooth 12.

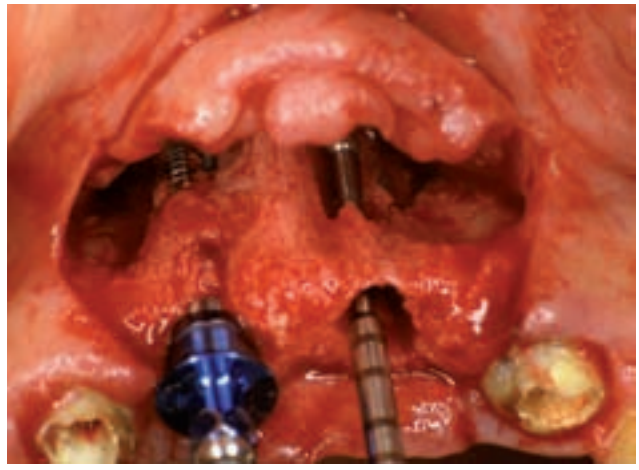


Fig. 3.11 Standard radiographs could not detect limited ridge width implant site numbers 8 and 9.

alveolar bone during treatment. This could lead to soft-tissue and/or artery damage, with the ensuing complications (5, 72). In addition to physical palpation and sounding, computer axial tomographic (CAT) scans are invaluable in identifying anatomic structures and variations before treatment. Measurements performed on a CAT scan will delineate the ridge's anatomic volume and contours that are favorable for implant placement (Fig. 3.13) (73–75).

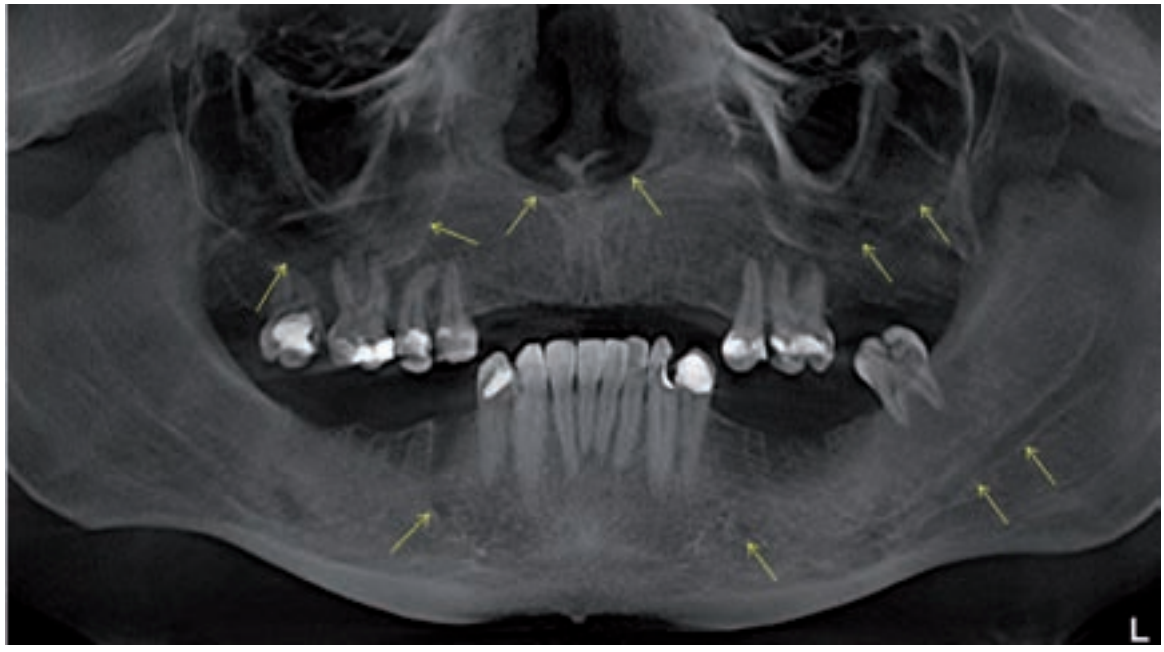


Fig. 3.12 Panoramic radiograph showing anatomic structures.

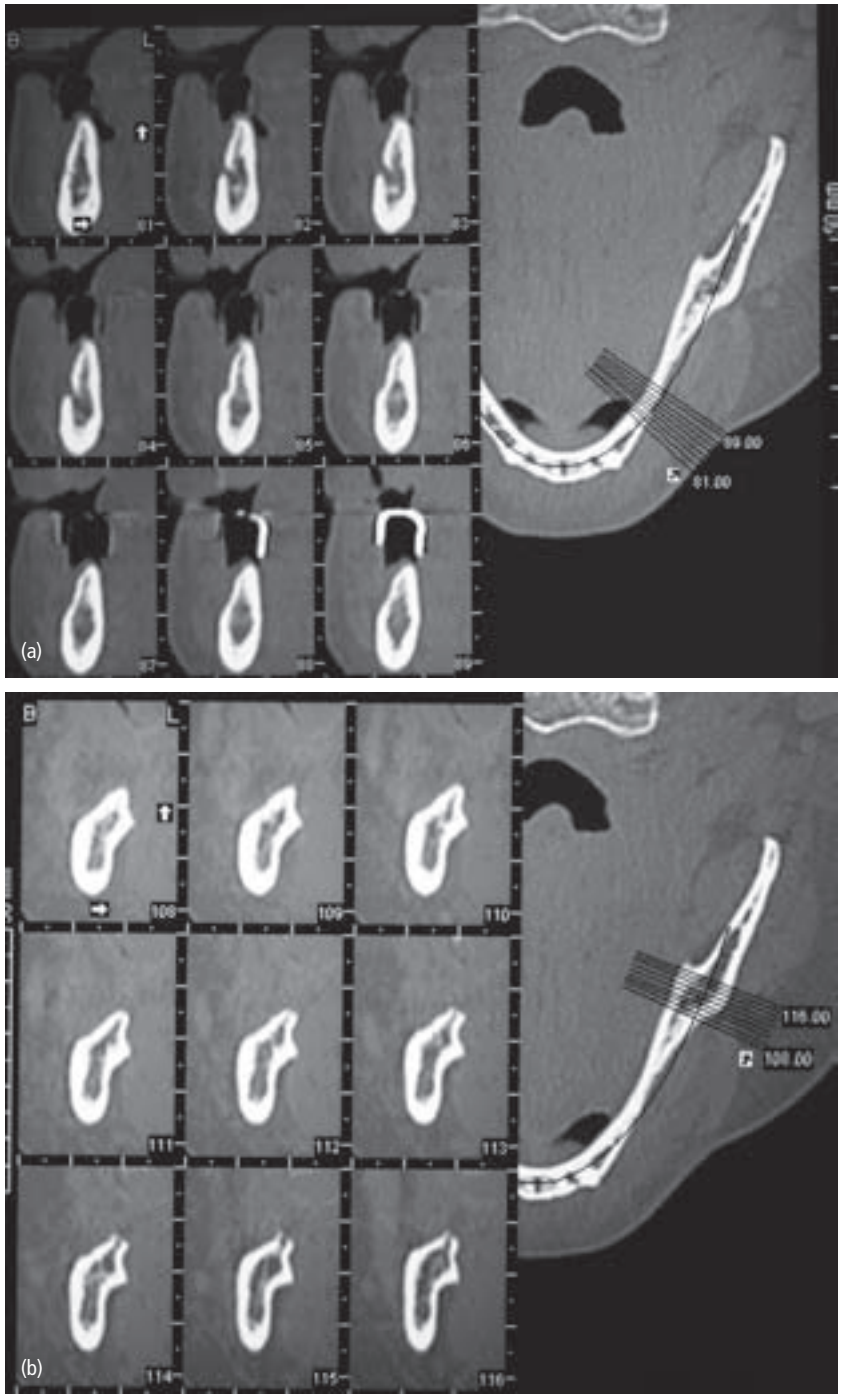


Fig. 3.13 (a) CAT scan of thin ridge; (b) CAT scan of undercut ridge.

Prevention of complications with proper planning

Localized site evaluation

In addition to a complete dental and periodontal charting, an intraoral examination for implant treatment includes evaluating the edentulous areas. Numerous factors need to be considered in this evaluation. If the ridge appears atrophic, then bone grafting may be necessary to allow implant placement (76, 77). An atrophic ridge often requires greater in-depth radiographic analysis. The existence of an atrophic ridge may signal a similar potential risk of atrophy to other areas should more extractions be required. Evaluation of the periodontal biotype provides insight into the potential for ridge resorption after extractions (78, 79). If the biotype is thin and scalloped the thinner plates could lead to more

resorption of the residual ridge after tooth extraction. Therefore, it may be advantageous to place a bone graft into the extraction socket at the time of tooth extraction to help preserve ridge width and height (Fig. 3.14a, b) (80–82). Preserved ridge volume will provide a more conducive site for future implant placement.

Periodontal tissue biotype can be classified as thin and scalloped or thick and flat (Fig. 3.15a, b) (83, 84). A thick and flat biotype can provide an edentulous ridge that is more favorable for implant treatment. The thicker biotype may provide a wider ridge for implant placement. Esthetically, this biotype does not require re-creating papillae that are long interproximally for the final prosthetics. Therefore, implant success from a functional and esthetic standpoint improves with the thick and flat periodontal biotypes (85, 86).

The proper number of implants to use must be determined in relation to the number of teeth to be placed restoratively. An implant to replace each missing tooth would be ideal, but is not always warranted (64, 87). Combining the restorative needs with the surgical options will allow the best restorative plan to develop. Areas that will be subject to higher occlusal loads benefit from more implants, and from implants that are wider and provide greater surface area for osseointegration (88, 89). Once placed, well-maintained and disease-free implants help to maintain bone levels just as teeth preserve alveolar ridge (90, 91).

Keratinized tissue, although not a prerequisite, is considered by many clinicians to be beneficial around implants (Fig. 3.16a, b) (92, 93). Therefore, potential implant sites should be evaluated for the amount of keratinized tissue present. If an area is lacking adequate keratinized tissue a soft-tissue graft can be performed before, at the time of implant placement, or at second stage surgery when the implant is uncovered and healing abutments are attached. Gingival grafts will provide a band of keratinized tissue to the ridge. Connective tissue grafts can augment attached soft tissue. This band of attached tissue will provide a strong cuff of soft tissue at

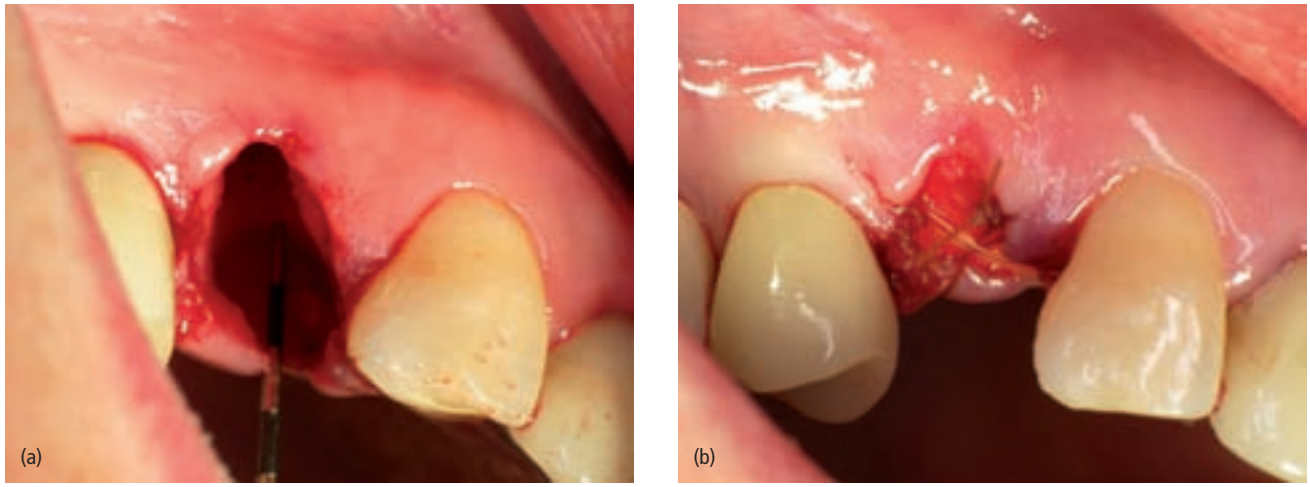


Fig. 3.14 (a) Socket preservation procedure; (b) socket preservation with bone graft and absorbable membrane.

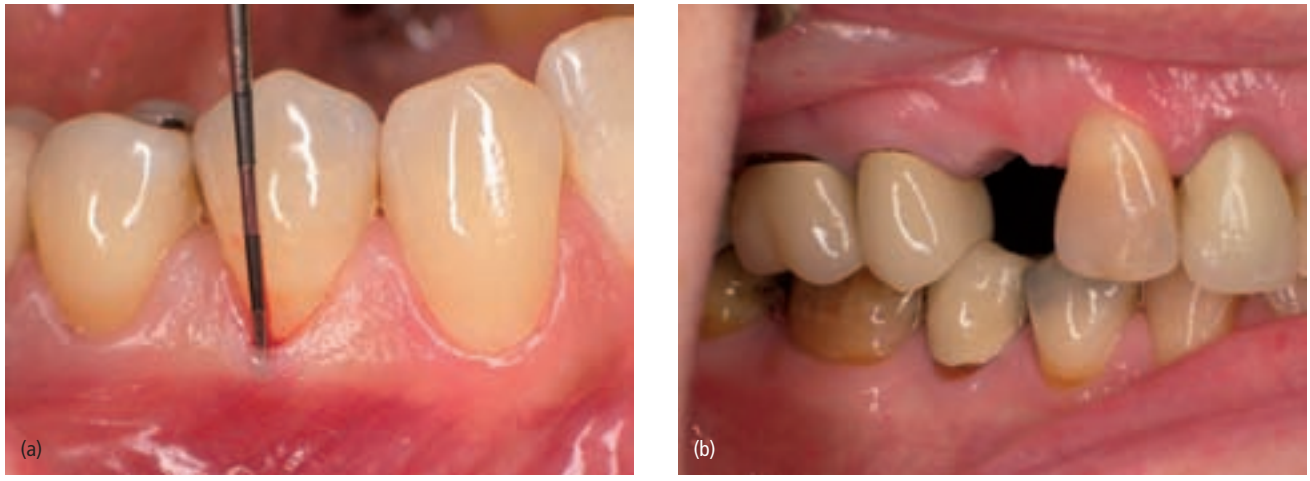


Fig. 3.15 (a) Thin and scalloped biotype; (b) thick and flat biotype.

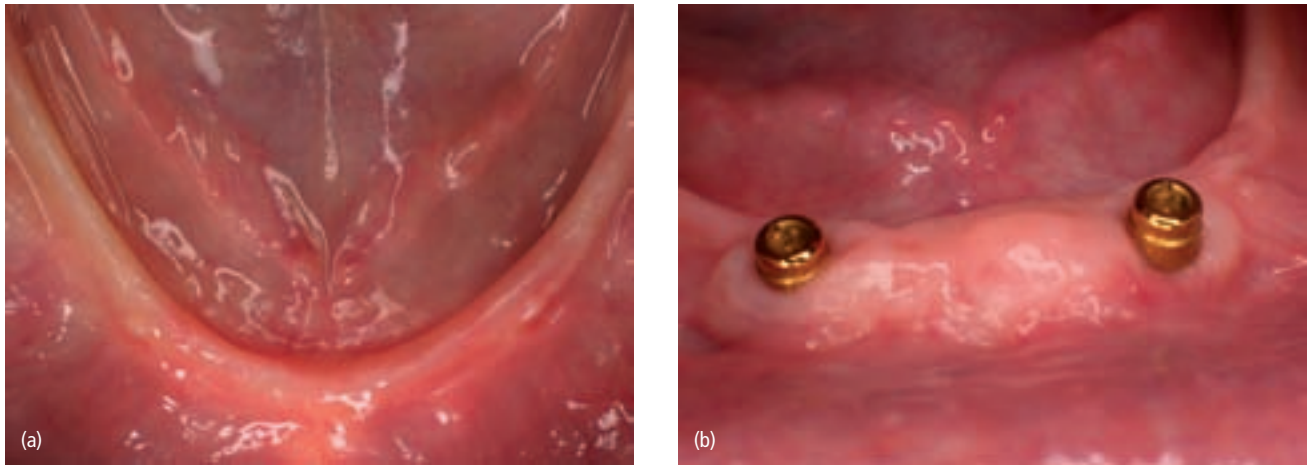


Fig. 3.16 (a) Edentulous ridge lacking keratinized tissue; (b) keratinized tissue augmented with soft tissue graft around implants.

the collar of the implant (94, 95). This may be especially important with the rough surface implants in use today (8, 96). Connective-tissue grafts usually provide a better esthetic enhancement than full-thickness gingival grafts, and this should be considered when dealing with esthetically sensitive areas (97, 98).

The intraoral examination should also evaluate tooth position and occlusion. Since implant dentistry involves restorative necessity, it is of fundamental importance to determine the relationship that exists between the proposed implant site, its respective restoration and the remaining occlusion. If a malocclusion exists, is it one that will affect the success of the implant restoration? Will the implant be subject to parafunctional forces, or stressed by occlusal overload? The intraoral examination should evaluate the occlusion, tooth malpositions, tooth supereruption, axial inclination, and rotation. If infections are present in the soft or hard tissue these should be addressed before initiating implant therapy. Periodontal therapy is essential for treating soft-tissue inflammation and reducing a potential nidus of infection for future implants. Periodontal therapy should be completed along with any necessary treatment for caries before implant placement.

Radiographs used in implant planning should be evaluated in regard to anatomic proximities. A full mouth series of X-rays is beneficial in analyzing the overall oral condition. Periapical and panoramic radiographs may both be required to analyze potential implant sites and avoid complications. A limitation of these radiographs is that they present existing conditions in only two dimensions (99–101) (see Chapter 4). When pathology is present on a radiograph, such as a periapical lesion, this should be treated accordingly. To avoid implant failure due to an adjacent periapical lesion, the lesion should be treated before implant placement (10, 102, 103).

Anatomic structures such as the mental foramen, inferior alveolar canal, and sinuses should be located to determine whether they are at risk with implant placement (Fig. 3.17). If risks appear to be present, further radiographic examination should be performed to evaluate the site fully. This includes the use of three-dimensional (3D) radiographic imaging, i.e. CAT or cone beam computed tomography (CBCT).

Root proximity presents a challenge that can impede implant placement. Radiographs are instrumental in planning the optimal implant position, and during placement to help monitor correct positioning. Radiographs taken during the implant placement drilling sequence can provide necessary visual feedback to help ensure avoidance of adjacent roots or vital anatomic structures (Fig. 3.18).

A patient's oral hygiene condition presents another important component to evaluate during the intraoral examination. If oral hygiene is poor, it could lead to additional breakdown, which could lead to either the functional or esthetic failure of the implant prosthesis. Instituting a program to improve the patient's oral

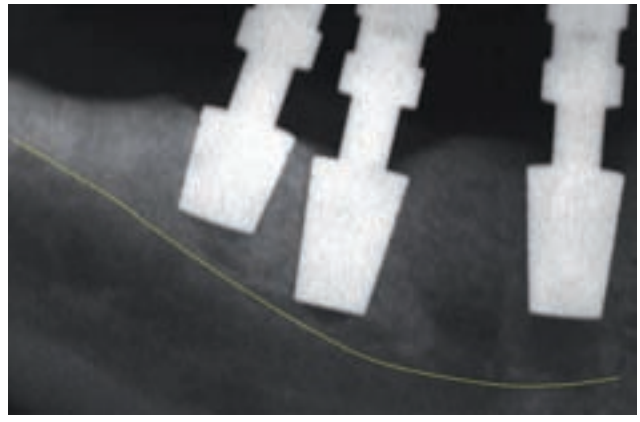


Fig. 3.17 Limited ridge height superior to inferior alveolar nerve.

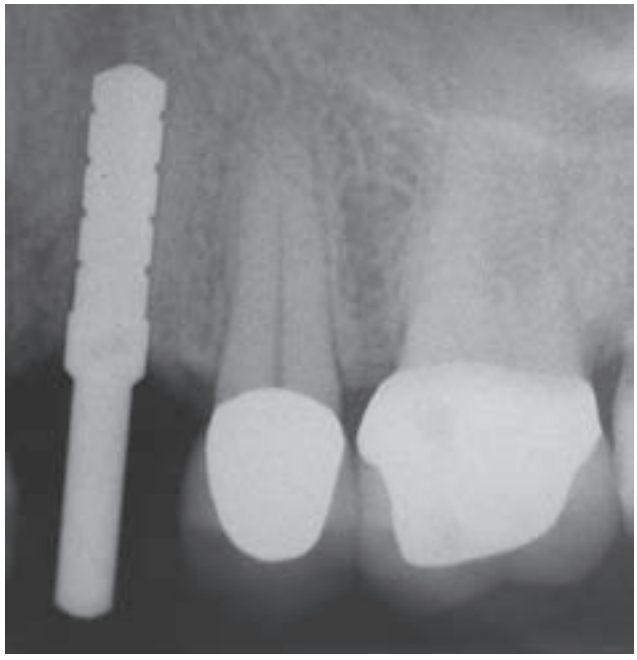


Fig. 3.18 Radiograph with direction indicator.

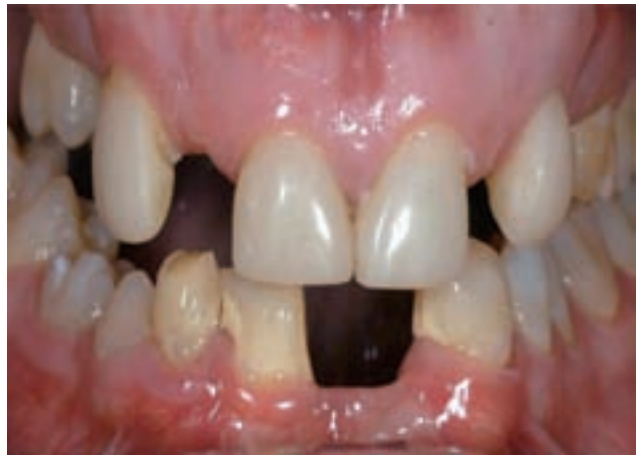


Fig. 3.19 Ectodermal dysplasia affecting dentition.

hygiene IQ and abilities in conjunction with a professional hygiene maintenance program has been shown to be invaluable in creating long-term successful results (104–106).

Issues associated with hereditary dental diseases are occasionally seen during an examination. Patients who demonstrate dental problems originating from these causes will require treatment plans that incorporate solutions aimed at overcoming the specific issue. For example, various treatment options should be considered for a patient with ectodermal dysplasia (Fig. 3.19) (31, 107).

Implant treatment planning

Once the initial patient examination and medical history consultations have been completed, implant treatment planning begins. The extent of information necessary to collect during the implant treatment planning phase varies from patient to patient. However, when thorough methods are implemented to provide information during the planning phase they may prove to be invaluable in avoiding future complications.

A decision tree (Chart 3.1) is provided to facilitate comprehension and execution of the procedures involved with implant planning. It directs the clinician through a process aimed at selection of treatment options during the planning phase. In addition, treatment planning options and considerations are provided for full arch, partial edentulous, and single tooth scenarios (Charts 3.2–3.5).

Clinical photographs taken of the patient are often helpful in evaluating the facial and oral conditions. This is especially true for any treatments planned in the esthetic zone. Photographs of the patient's smile, teeth, gingival contours, and papillae can provide valuable insight when considering potential treatment options. Reviewing photographs taken of a patient may help highlight potential areas of concern. What degree of gingiva is displayed when the patient is smiling? Is there symmetry between the left and right sides? Are there any esthetic concerns that were missed during the patient's examination? Are there ridge deformities present that could hamper implant placement or pose esthetic issues? (Fig. 3.20).

The edentulous ridge that will be the prospective implant site needs to be evaluated for various factors. Adequate height and width of bone needs to be present to allow for circumferential containment of the implant when placed. In addition, a ridge should be evaluated for the spatial relationship it has to adjacent teeth or an opposing arch. A ridge may have adequate volume for implant placement, but owing to ridge atrophy the implant may need to be placed significantly lingual or apical to adjacent teeth (Fig. 3.21a–c) (108–110). This could create a situation that would make restorative or maintenance treatment difficult. A ridge may be so significantly angled that it should be avoided as an implant site (Fig. 3.22) (111, 112). A severe undercut may exist which increases the risk of perforation through the cortical plate while drilling. An incidence of perforation can pose a significant hazard, especially if it occurs next to a vital structure such as a major blood vessel (113, 114). Even when an implant can be placed without negative consequences, a ridge defect could pose an esthetic concern. A patient with a high smile line may show a buccal ridge concavity under the restoration. Surgical augmentation by hard or soft tissue can reduce the concavity. Another alternative includes the use of pink porcelain or acrylic added to the final restoration (Fig. 3.23a, b) (115, 116).

Chart 3.1

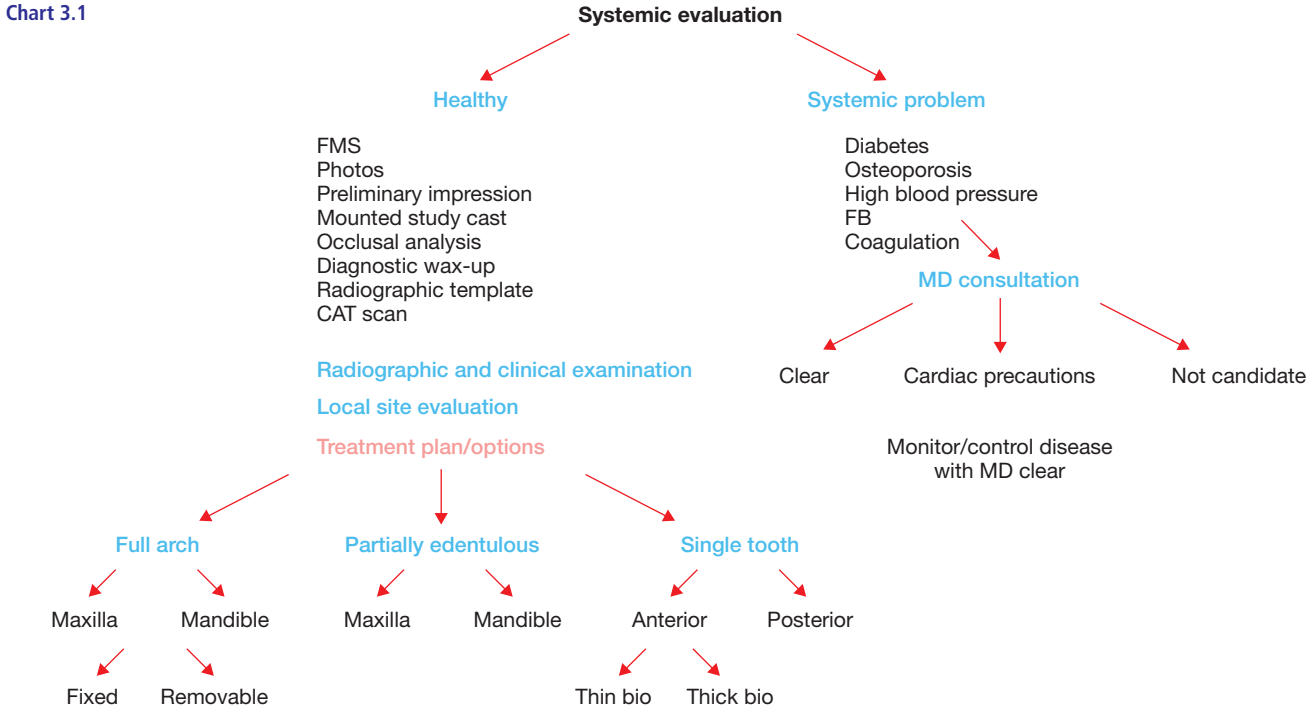
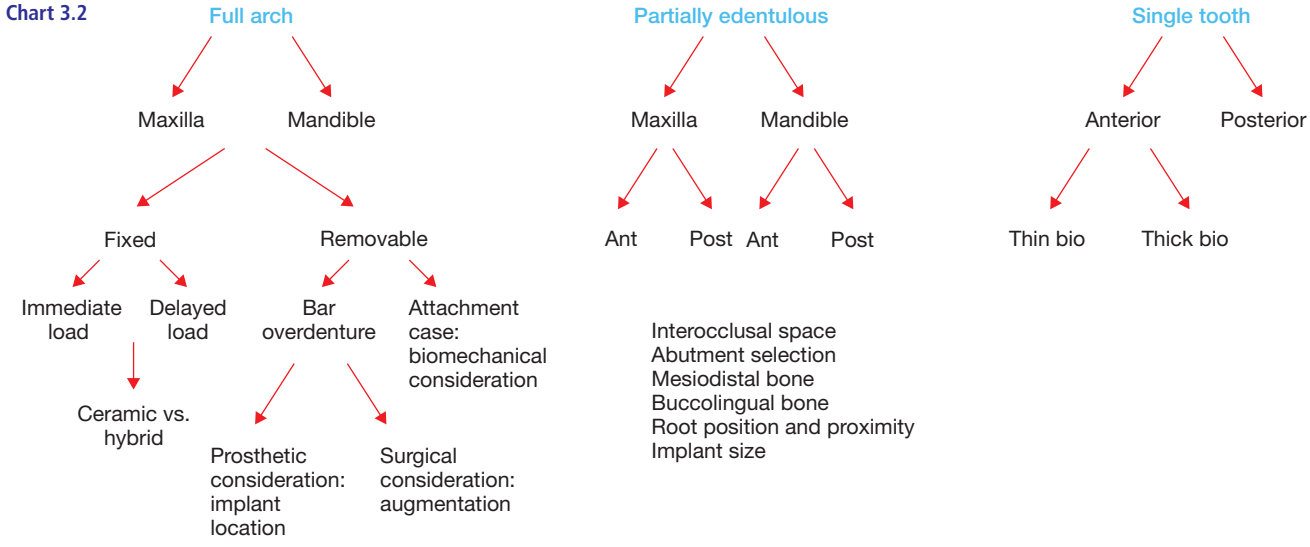


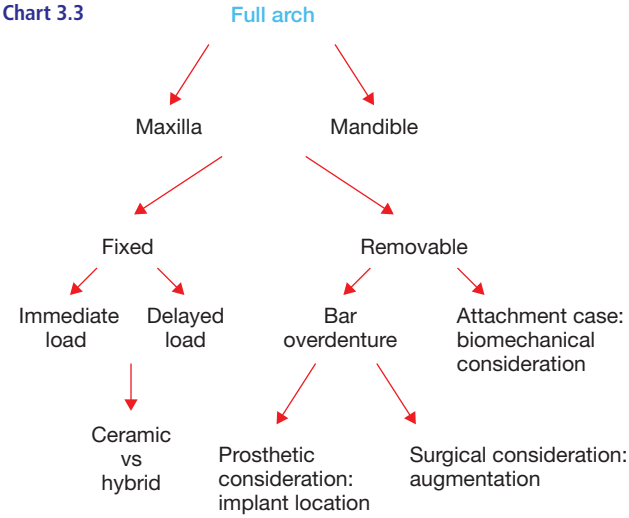
Chart 3.2



Preliminary impressions, and when necessary a bite registration, can provide mounted study casts that will display occlusal issues. The casts allow a clear examination of the intra-arch conditions, such as mesiodistal spacing, ridge and tooth positions, as well as opposing arch issues including interarch space (Fig. 3.24) (117, 118). A comprehensive evaluation of these elements can help avoid potential problems later during the surgical or restorative phase. The study casts also demonstrate ridge atrophy, both buccolingually and occlusally–apically. These defects can be more easily related to adjacent teeth or the opposing arch on the mounted study casts, thereby providing additional information for the viability of both implant treatment and bone grafting augmentation.

Other areas of concern requiring evaluation in order to formulate an implant treatment plan are those that deal with anatomic issues. Muscle strength and pull, oral habits, facial profile, and lip support all play a role in determining treatment options (119–121). The role played by each of these in the overall treatment plan depends on many factors. How many teeth need to be replaced? Will additional hard- or soft-tissue augmentation be required? What type of provisionalization will be

Chart 3.3



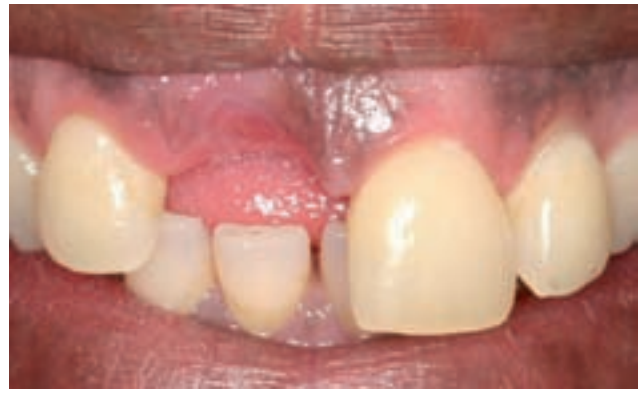


Fig. 3.20 Ridge deformity causing esthetic concern.

Chart 3.4

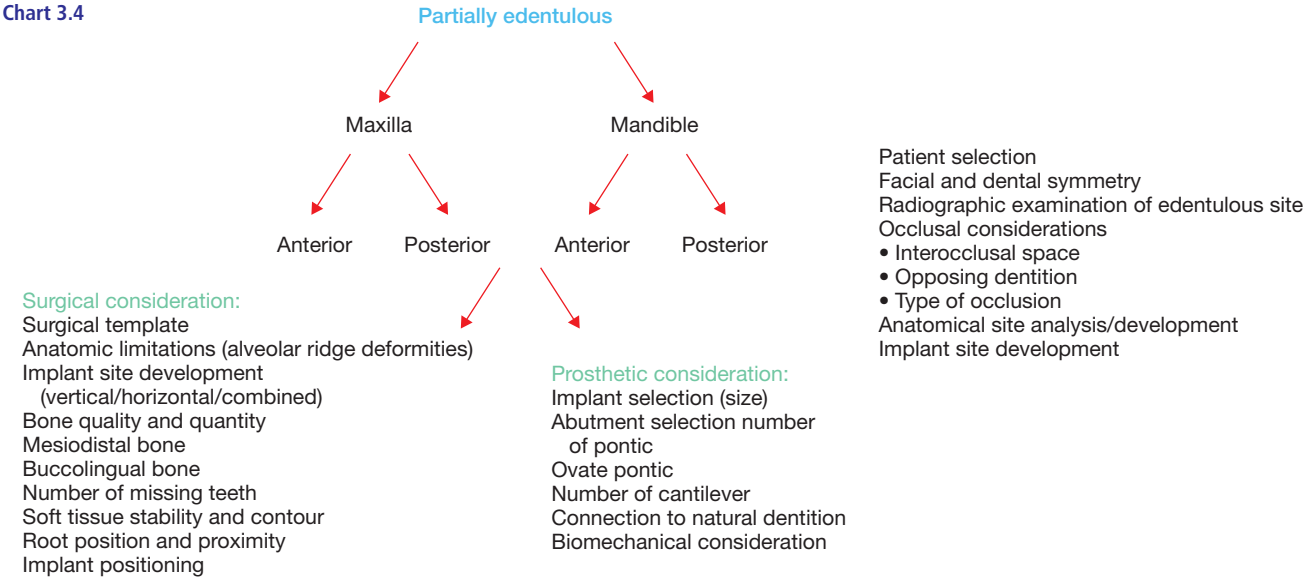
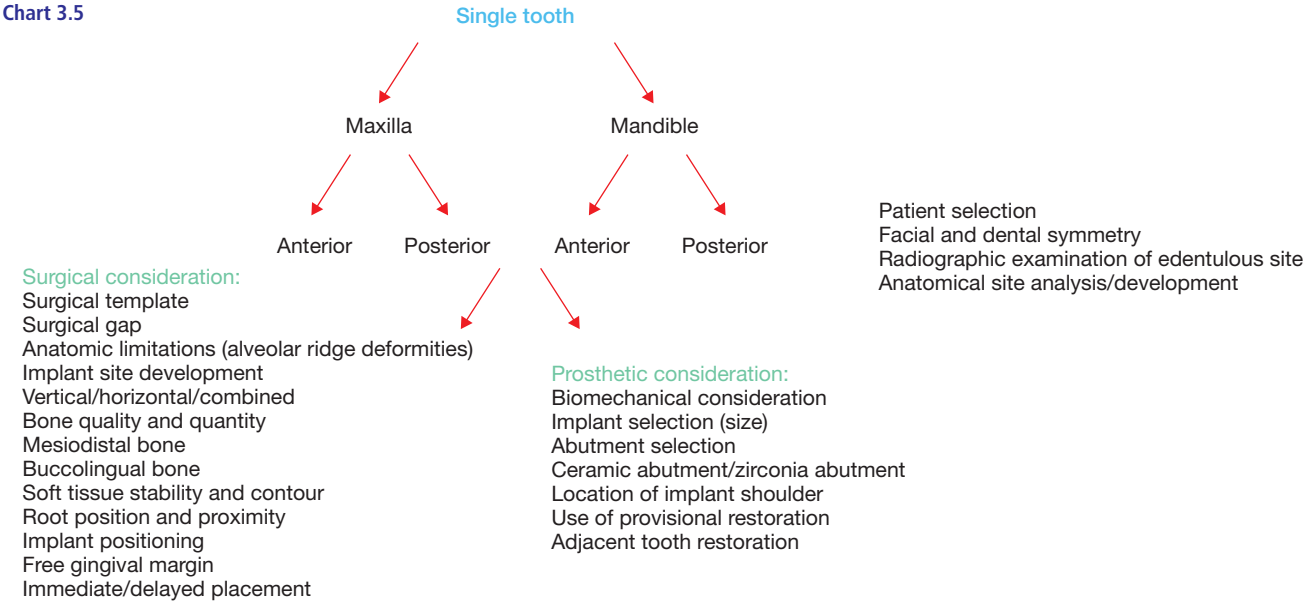
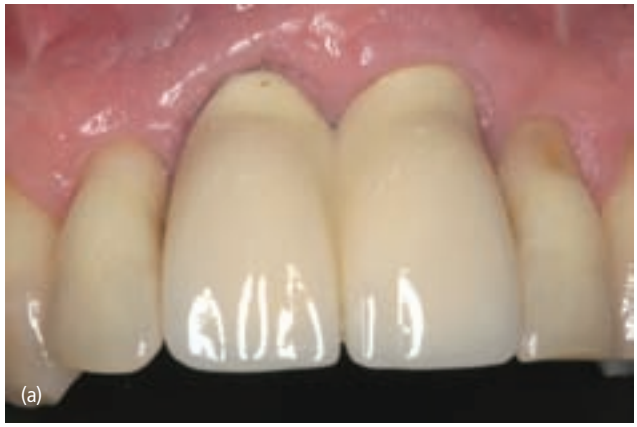
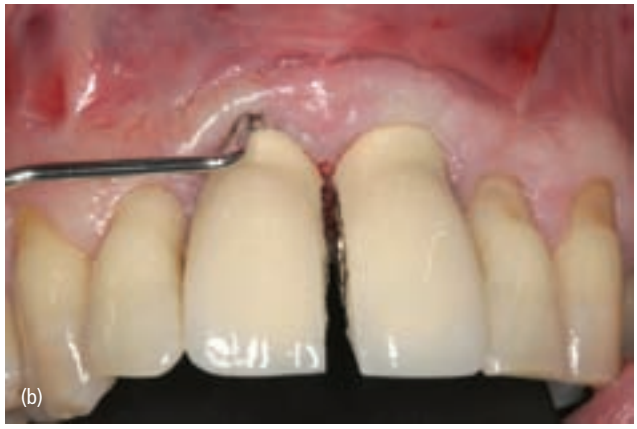


Chart 3.5







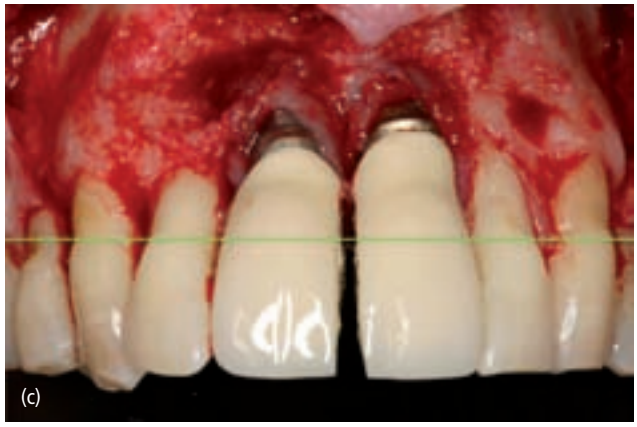


Fig. 3.21 (a) Non-optimal implant placement due to ridge atrophy causing esthetic compromise; (b) increased probing depth around non-optimally placed implants; (c) flap reflection displays apically positioned implants in comparison to adjacent teeth cementoenamel junction (CEJ) (green line at level of CEJ of adjacent teeth).

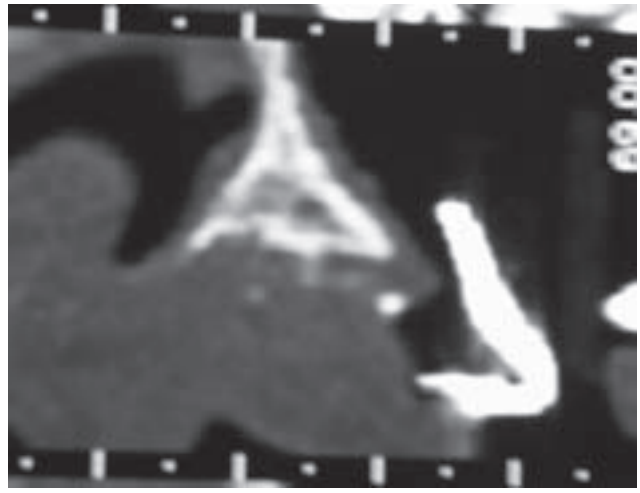
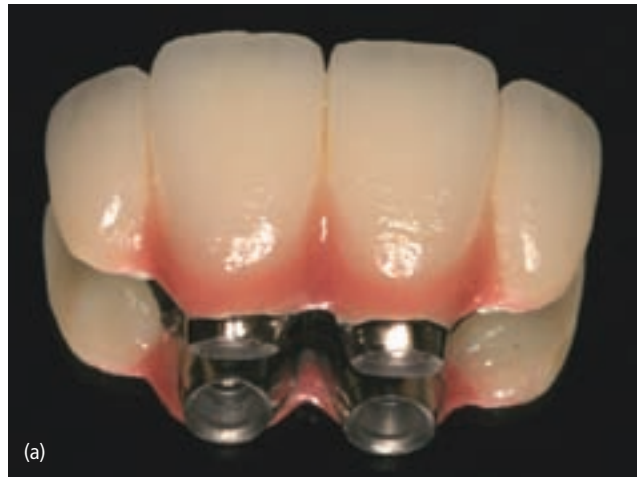


Fig. 3.22 Radiographic cross-sectional view of severely angled ridge.



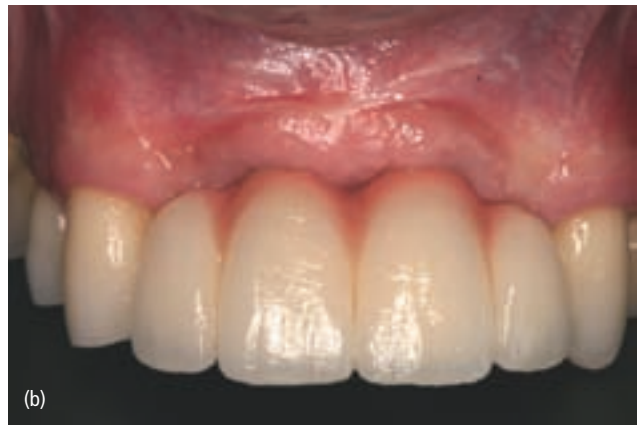


Fig. 3.23 (a) Pink porcelain used for final restoration; (b) inserted final restoration with pink porcelain.

used? What are the esthetic concerns? Will the final restoration be removable or fixed? Will the implants be immediately loaded?

Primary flap closure is an essential element of bone augmentation. Implant placement with simultaneous bone augmentation creates flap pressure. If this pressure is increased owing to heavy perioral muscle strength or pull, it can cause flap dehiscence and failure (Fig. 3.25) (19, 122). Evaluation of the perioral muscle strength and pull will provide valuable insight into the implant surgeon's ability to attain non-tension primary closure.

Oral habits, facial profile, and lip support are also key points to consider in this process. They too can affect either the surgical aspect of treatment or restorative requirements. For example, if the anterior maxilla has

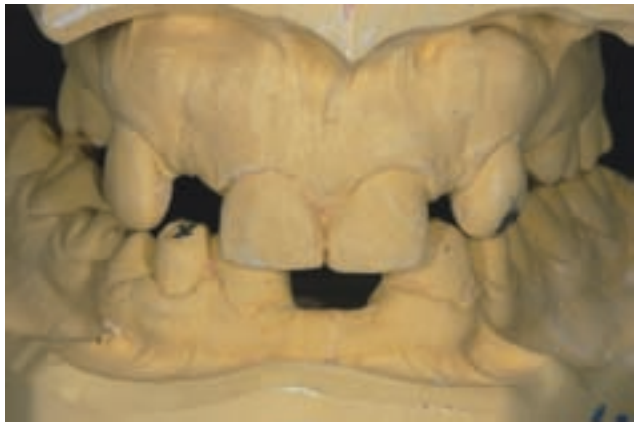


Fig. 3.24 Mounted study casts for occlusal analysis.

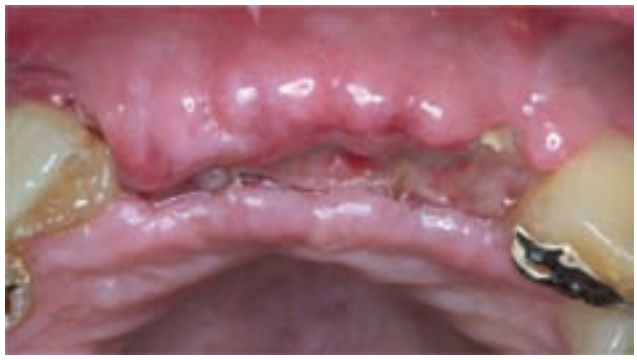


Fig. 3.25 Flap dehiscence.

suffered significant ridge atrophy, then lip support will need to be considered with the final prosthesis. This may dictate that the final restoration be either a removable prosthesis or a hybrid type (see Chapter 9).

The information gathered during this process plays just as critical a role in determining the final treatment plan as it does in developing the stages of treatment. Decisions regarding the stages of therapy and the techniques implemented must be developed through a full understanding of the results desired and the issues that need to be surmounted. Questions that need to be addressed are: Should implant placement be a one- or two-stage technique? Are the implants to be placed immediately into an extraction socket or have delayed implant placement? Should the implants be immediately temporized or loaded?

Each case displays its own specific circumstances, which need to be considered in the decision process. To consider placing an implant into an immediate extraction socket it must be able to attain primary stability at the time of placement. This requires 4–5 mm of natural bone apical to the socket of the extracted tooth (see Chapter 18). In addition, with or without bone grafting being utilized, the socket must have the potential to provide circumferential bone integration to the implant (123, 124). When a one-stage implant technique is considered over the traditional two-stage technique, a similar finding should be ascertained (125, 126). However, for a one-stage technique proper gingival tissue contour and consistency including adequate attached keratinized tissue should be present. When considering immediate loading or temporization of implants there are additional concerns to be weighed. Loading refers to putting the implant into occlusal function or potential oral stimulation (2, 127). Loading an implant can potentially be detrimental to osseointegration of the implant (35, 98, 128) (see Chapter 20). Specific conditions will affect the outcome. For example, implants splinted within cross-arch stabilization are amenable to an immediate loading protocol (Fig. 3.26) (129, 130). However, loading a single implant on placement poses a significant risk. If a single implant requires immediate temporization at the time of implant placement, it is critical that the provisional crown be fabricated to avoid any occlusal forces. All these factors and decisions will determine the techniques used and the stages required.

Creating a wax-up of the projected final restorative outcome is beneficial for planning implant cases (Fig. 3.27). In partially edentulous cases a wax-up of the ideal restored tooth position will provide guidance for both the surgeon and the restorative dentist. The surgeon will be better able to analyze projected tooth position in relation to the remaining alveolar ridge. Implant position and the potential need for bone grafting can be determined before surgery, allowing the risks, complications, and shortfalls of implant treatment to be fully understood by both the patient and the restorative dentist.

The wax-up provides the restorative dentist with a tool to determine the functional and esthetic outcome potential. The number of sites that may require restorations can be more fully visualized. The position and number of implants required to support the restoration properly can be determined. The need for more extensive restorative care elsewhere in the oral cavity can be evaluated as well. This will help produce a long-lasting functional and esthetic result.

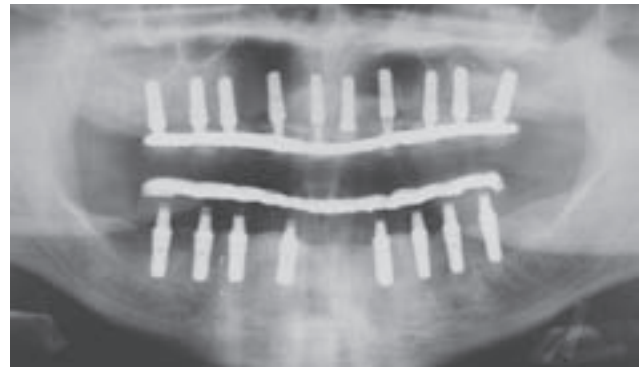


Fig. 3.26 Immediate loaded implants with cross-arch splinting for stabilization.

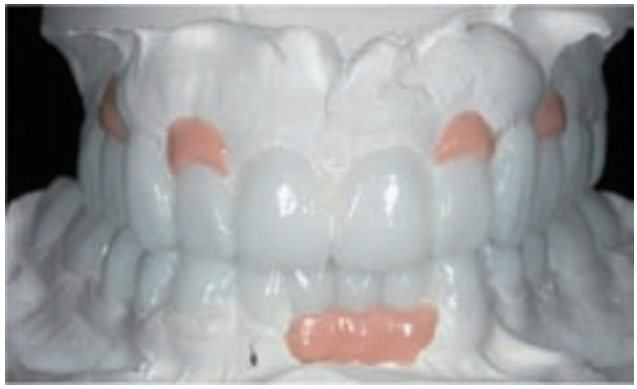


Fig. 3.27 Diagnostic wax-up for treatment planning.

The restorative dentist can decide with the patient on the final prosthesis design. Will it be fixed or removable? The answer to this question can change the demands on the surgeon and on the selected implant site (Fig. 3.28). A prosthesis that will be removable or of a hybrid design does not have the same implant positioning demands. This could alter the need for other treatments such as ridge augmentations or sinus augmentations.

In fully edentulous cases it is prudent to evaluate the patient's current dentures. Do the dentures fit well? Is the vertical dimension correct? How much lip support is required by the denture flange? The answer to these questions will provide a guide for planning the restorative option of choice. If an edentulous patient desires an implant-supported removable prosthesis and does not currently have any removable prosthesis, it is advisable first to establish the patient's vertical dimension and occlusion. This information can then be used to establish implant placement relationships, whether the patient opts for a fixed or a removable prosthesis.

Radiographic surgical templates

Radiographic examination is an essential component of the implant treatment planning process. During this phase the ridge is analyzed to verify that it meets the necessary criteria for implant placement. However, the question arises: how do we relate the planned restorative position to the proposed site seen on the radiograph? This can be accomplished best through the use of a radiographic surgical guide (131, 132). The restorative wax-up that was developed during the implant treatment planning phase can be duplicated to fabricate the acrylic surgical guide.

To relate the restorative plan to the ridge and be visible on the radiograph, the template requires the incorporation of radiographic markers (Fig. 3.29). Numerous methods have been described in the literature describing how this can be accomplished (133, 134). Often radiographic markers are placed on the buccal and lingual surface or through the center of the replicated tooth. Barium sulfate, which is radiopaque, can also be used to fill the entire replicated tooth in the template (Fig. 3.30) (103, 135). Regardless of which method is employed to fabricate the template, the objective is to relate a position on the radiograph to the intraoral site. Many computer-assisted techniques have been developed and marketed to enable this relationship to be correlated; however,

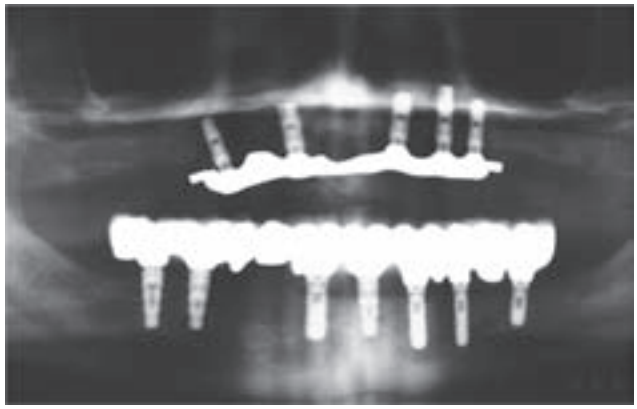


Fig. 3.28 Panoramic radiograph of fixed and removable implant-supported prosthesis.

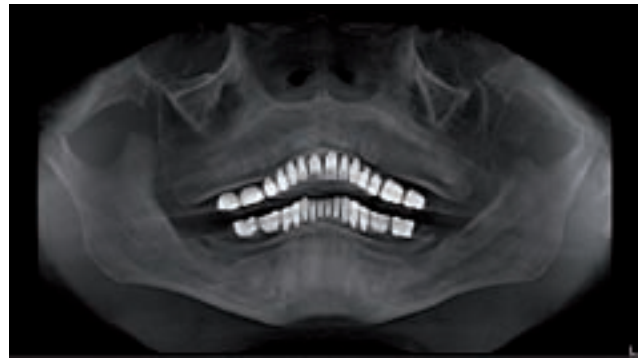


Fig. 3.29 Panoramic radiograph displaying template with radiographic markers.

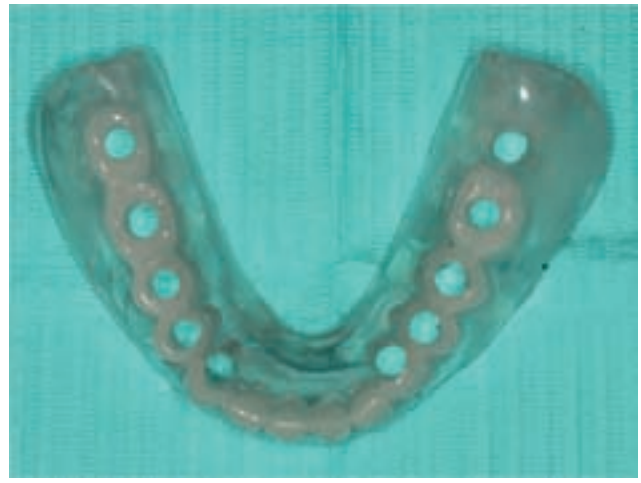


Fig. 3.30 Surgical guide with barium sulfate teeth as markers.

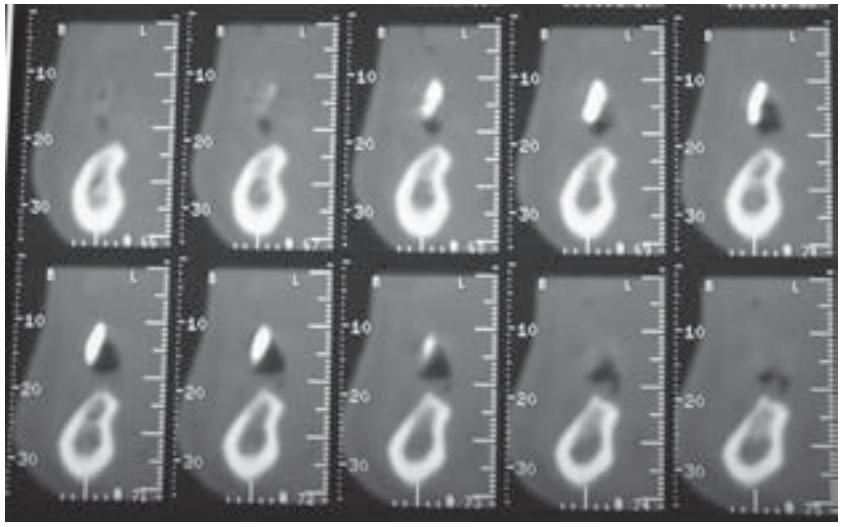


Fig. 3.31 CAT scan cross-sectional views.

they all rely on the basic premise of using a radiographic surgical template.

Denta-scan, CAT scan evaluation, and CBCT

Once the radiographic surgical template has been fabricated, it is placed in the patient's mouth for radiographic examination of the ridge. Usually, a periapical or panoramic X-ray is taken. In most cases this step completes the implant treatment planning process. If the radiograph plus any other collected information is sufficient, implant treatment can proceed. However, there are times when a periapical or panoramic radiograph may not be sufficient, and further radiographic investigation is warranted. This may occur when questions arise pertaining to spacing issues, anatomic concerns, or bone volume and they cannot be ascertained by two-dimensional radiographs. In these cases it is beneficial to have the patient undergo a Denta-scan, CAT scan examination or CBCT radiograph. The patient can wear the radiographic surgical template for these radiographs.

The Denta-scan, CAT scan examination, and CBCT are computer-generated radiographs that are reconstructed to show all three dimensions. The main advantage pertains to the cross-sectional views, whereby the radiograph can show a buccolingual view of the ridge (Fig. 3.31) (70, 136). Radiographic cross-sectional analysis provides a significant advantage in evaluating a potential implant site. Ridge size can be determined in both the buccolingual and occlusal–apical directions. The proximity of anatomic vital structures can be evaluated from this dimensional view. Undercuts in the morphology of the ridge and the position of the buccal and lingual plates can be evaluated. Anatomic vital structures, ridge width, and position are all more clearly delineated. In addition, the radiographic ridge can be related to the ideal tooth position as seen on the radiographic surgical template. The radiographic surgical template can then be used intraorally as a surgical guide to facilitate proper implant positioning (Fig. 3.32) (137, 138). Using 3D radiographic imaging allows implant placement to be planned with a marked reduction in the factors that can cause complications and failures.

Once compiled, the 3D computer-generated data need to be in a form in which they can be evaluated. This can be accomplished in numerous ways. The data are generated in a form called Dicom data. These data need to be reformatted into a form that can be printed on paper or radiographic film for evaluation. The data can also be placed on a compact disk. Often, the data are transferred to one of the marketed software packages sold by various companies. The data can then be placed in the computer for evaluation and treatment planning. The

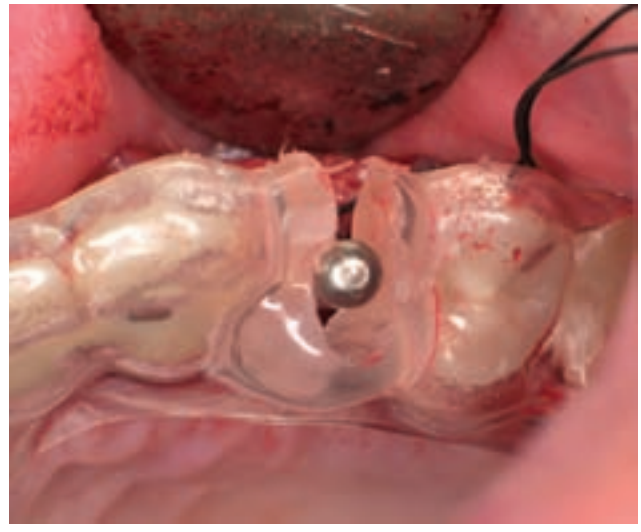


Fig. 3.32 Surgical intraoral guide.

computer software provides many treatment planning advantages and abilities for evaluating implant sites, which can help avoid potential surgical implant complications (Fig. 3.33) (110, 139). The computer software advantages range from allowing an accurate measurement of ridge size to virtual implant placement and abutment evaluation.

The data acquired through radiographic examination in conjunction with other clinical findings provide the information necessary for analyzing the implant site. To finalize implant site analysis and the implant treatment plan, the information gathered must be combined and evaluated in its entirety. Implant site analysis depends on radiographic and clinical findings, as well as overall knowledge and experience on what constitutes the necessary elements for implant success. The findings should be considered as they relate to a range of factors and questions. Is the site in the maxilla or mandible? What is the anticipated bone density? Is the implant to be placed in the posterior or anterior part of the mouth? Will the site be in an esthetic or non-esthetic area? What is the final prosthesis, and what will be the opposing occlusion? Will adjacent teeth require root canal, extraction, or restorative treatment? Will the implant site require bone grafting, and if so how much, and in which locations? Will the implants be stable enough for placement at the time of ridge augmentation, or sinus augmentation, or will the case need to be staged? Will soft-tissue augmentation be necessary, and when will it be performed? As soon as the answer to these questions can be obtained from the information gathered, the implant treatment plan can be finalized and the risk of complications and failures significantly reduced.

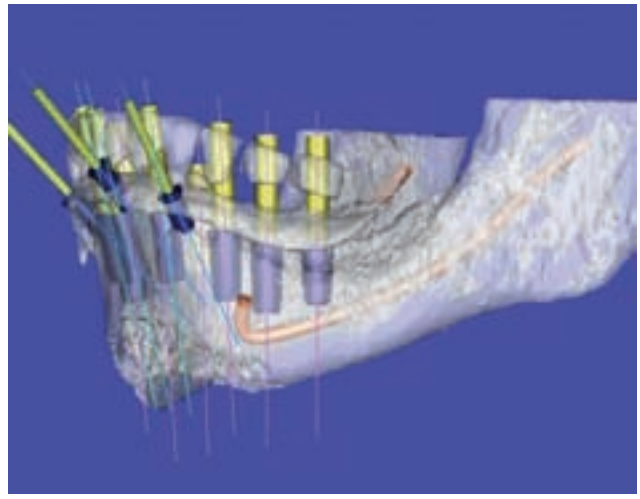


Fig. 3.33 Computer software 3D planning.

Avoiding implant complications

Staying focussed on restorative requirements

The first step in managing implant failures and complications is avoiding them in the first place. To accomplish this it is important to stay focussed on the objective of implant treatment. Implant treatment is really a restorative treatment which is provided through a surgical procedure. Therefore, it is important to stay focussed on the restorative goals. Plan for a restorative outcome and place implants based on the restorative requirements to achieve a restoratively acceptable result (140).

Consider the specifics of the case and how it affects the final restoration. Consider the difference between the arches. The maxilla has esthetic concerns, and the mandible has more cortical bone, and vital anatomic structures. How will this affect treatment planning? Is the treatment for a full arch, partially edentulous area, or a single tooth? What particular concern does each one of these raise, and what is the best way to deal with them? Will treatment be for the posterior or anterior? Any salient issues posed by these differences require reflection so that treatment planning avoids situations that can lead to implant treatment complications and failure.

Knowledge is a double-edged sword

It is important for the less experienced clinician to realize that it's what you don't know that will get you into trouble. Like everything else in dentistry, the more you learn about implant planning and treatment, the more you realize that there is much more to know. Therefore, know your limitations, and realize that you cannot foresee what you don't know. Build relationships and use a team approach when necessary to plan and treat cases that would benefit from a synergistic approach. Circumspect planning and proper team support can prove to be extremely beneficial for a successful outcome, and one that limits potential failures and complications.

Develop an implant planning and treatment triad. The implant triad consists of the surgeon, restorative dentist, and laboratory technician (141, 142). A strong triad will provide invaluable support. It can be a tremendous source of knowledge, and provide an excellent forum for open discussions and exchange of ideas. The establishment of a strong interactive implant triad will provide necessary information for proper implant treatment planning and also personal growth in the field of implant dentistry. In addition, each member of the triad could benefit from a cross-referral relationship. Even for practitioners who provide both surgical and restorative treatment, a properly developed triad could prove helpful in planning or treating cases that require a greater degree of support.

Surgical techniques

Avoiding implant complications caused by planning during the surgical phase requires meticulous preparation. First, use surgical planning tools that can help plan the surgery and reveal potential complications. These tools consist of those already discussed, such as periapical and panoramic radiographs, radiographic surgical templates to identify ideal implant locations, and 3D computer software for positioning implants and avoiding vital anatomic structures. Second, use correct surgical techniques for implant placement. This encompasses all phases of the surgery from the proper incision line to elevating the flap, osteotomy preparation, implant placement, and final closure. Determine whether bone grafting or sinus augmentation will be required, and be prepared for the potential problems this may pose. Will the implant be placed at the same surgical visit? Will the incision line need to be different? How will closure be affected? When these types of question have been evaluated the surgical phase itself will proceed more predictably.

Consider all manufacturers' recommendations that may be specific to the implant system being used and determine whether it is a one- or two-stage approach. A two-stage approach requires secondary surgery to expose the implant platform to the oral cavity. This occurs after initial healing and osseointegration of the implant. During second stage surgery a healing abutment or temporary abutment is attached to the implant, in preparation for an implant impression and fabrication of the final restoration. Implant placement in an apico-occlusal position should also follow manufacturers' recommendations. Implant design can vary and the recommended placement of the platform can be subcrestal, crestal, or supracrestal. However, implant placement should also consider the ideal apicocoronal position as it relates to adjacent teeth. Ideally, the implant platform should be positioned 2–3 mm apically to the buccal cementoenamel junction level of the adjacent teeth. If the position is more coronal it could allow the metal platform to become supragingival, affecting esthetics. If the position is more apical it makes it more difficult to fit prosthetic parts onto the implant, and may create a more difficult maintenance issue (143, 144) (see Chapter 9).

The third important point in surgical planning is to match your surgical skills to the level of care required. Realize that different cases will require varying degrees of skill and experience. In this regard, implant treatment can be divided into different anatomic groups. Each group is associated with different criteria of risk (51, 145). The anterior maxilla is considered to be the most challenging area for implant treatment. This is due to issues pertaining to the volume of bone, angulation of the ridge, and the esthetic ramifications. The least challenging would be the anterior mandible. Here the quality of bone, volume of bone, and lack of anatomically vital structures reduce the implant placement challenges (69, 146).

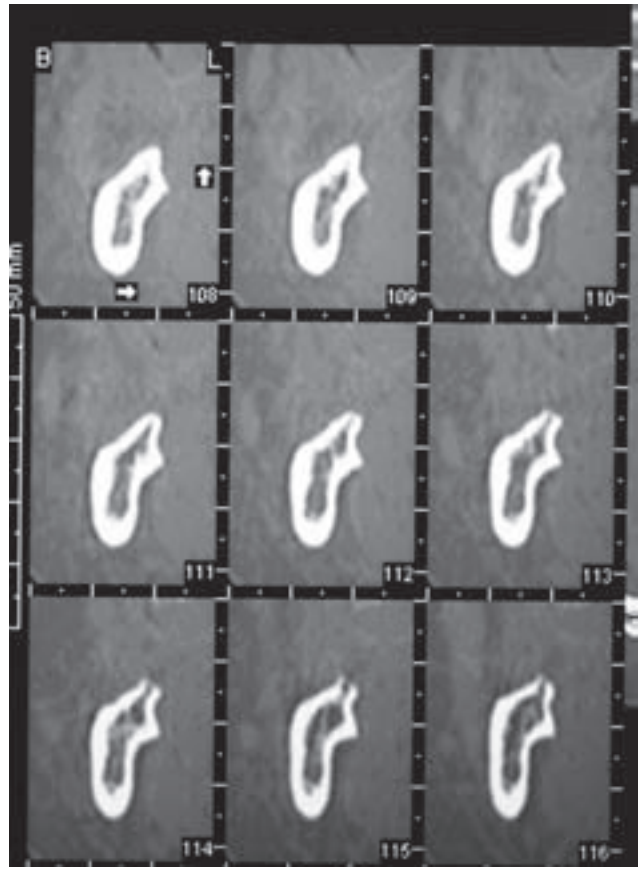


Fig. 3.34 CAT scan showing mandibular lingual undercut.

The posterior mandible is considered the highest risk area for implant treatment. This is because of the proximity to the mandibular alveolar canal and the mental foramen. In addition, the mandible can have lingual undercuts in this area (Fig. 3.34) (23, 53). This condition makes perforation of the lingual cortex while drilling a potential risk. The second most dangerous area to treat is the posterior maxilla. The maxillary sinus is at risk of perforation and having implants unintentionally displaced into the sinus cavity (147, 148). It is important that during the implant treatment planning phase the difficulties unique to each area be considered and weighed. Training, experience, and continuing education will provide the expertise required to master more difficult cases.

Treatment of complications related to implant planning

Examples of treatment of complications caused by misdiagnosis and poor planning as described in this chapter are presented in Chapter 25.

Take-home hints

- The initial interview should be thorough and include obtaining a complete medical, dental, and social history to assess the patient profile, expectations, systemic problems, and medications that have been taken in the past, and are currently being taken.
- Evaluate any limitations to treatment and discuss these with the treating team, the patient and, when necessary, the patient's physician.
- Use all appropriate records, radiographs, mounted casts, and clinical examination before deciding on treatment options.
- Plan the implant restoration from the top–down.
- Know your patient and present treatment options with this knowledge.
- Surgical planning should be completed with full knowledge of the patient's mental and physical state as well as local site evaluation.
- Follow the decision trees outlined in this chapter to minimize treatment complications.
- Stay focussed on restorative requirements.
- Use (or gain) the knowledge and experience to evaluate treatment risks. The best treatment for a complication is to avoid it.
- Following patient evaluation and treatment planning, evaluate your own knowledge, experience, and skills before deciding whether to treat or refer the patient.

References

1. Adell R, Lekholm U, Rockler B, Brånemark PI. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. *J Oral Surg* 1981; **10**: 387–416.
2. Lindquist LW, Carlsson GE, Jemy T. A prospective 15 year follow-up study of mandibular fixed prosthesis supported by osseointegrated implants. *Clin Oral Implants Res* 1996; **7**: 329–36.
3. Zarb GA, Schmitt A. The longitudinal clinical effectiveness of osseointegrated dental implants: the Toronto study. Part I: Surgical results. *J Prosthet Dent* 1990; **63**: 451–7.
4. Esposito M, Hirsch JM, Lekholm U, Thomsen P. Biological factors contributing to failures of osseointegrated oral implants (II). Etiopathogenesis. *Eur J Oral Sci* 1998; **3**: 721–64.
5. Kalpidis CD, Setayesh RM. Hemorrhaging associated with endosseous implant placement in the anterior mandible: a review of the literature. *J Periodontol* 2004; **75**: 631–45.
6. Luna AH, Passeri LA, de Moraes M, Moreira RW. Endosseous implant placement in conjunction with inferior alveolar nerve transposition: a report of an unusual complication and surgical management. *Int J Oral Maxillofac Implants* 2008; **23**: 133–6.
7. McDermott NE, Chuang SK, Woo VV, Dodson TB. Complications of dental implants: Identification, frequency, and associated risk factors. *Int J Oral Maxillofac Implants* 2003; **18**: 848–55.
8. Moy PK, Medina D, Shetty V, Aghaloo TL. Dental implant failure rates and associated risk factors. *Int J Oral Maxillofac Implants* 2005; **20**: 569–77.
9. O'Sullivan D, King P, Jagger D. Osteomyelitis and pathological mandibular fracture related to a late implant failure: a clinical report. *J Prosthet Dent* 2006; **95**: 106–10.
10. Quirynen M, Vogels R, Alsaadi G, Naert I, Jacobs R, van Steenberghe D. Predisposing conditions for retrograde periimplantitis, and treatment suggestions. *Clin Oral Implants Res* 2005; **16**: 599–608.
11. Alsaadi G, Quirynen M, Komarek A, van Steenberghe D. The impact of local and systemic factors on the incidence of oral implant failures, up to abutment connection. *J Clin Periodontol* 2007; **7**: 610–17.
12. Mombelli A, Gionca N. Systemic disease affecting osseointegration therapy. *Clin Oral Implants Res* 2006; **17**: 97–103.
13. Amrein PC, Ellman L, Harris WH. Aspirin-induced prolongation of bleeding time and perioperative blood loss. *JAMA* 1981; **245**: 1825–8.
14. Míka P, Behounek J, Skoták M, Nevsímal L. Complications and risks associated with an anticoagulation therapy combining low molecular weight heparin and Warfarin after total replacement of large joints – our experience. *Acta Chir Orthop Traumatol Cech* 2004; **71**: 237–44.
15. van Steenberghe D, Quirynen M, Molly L, Jacobs R. Impact of systemic diseases and medication on osseointegration. *Periodontol 2000* 2003; **33**: 163–71.
16. Brennan MT, Wynn RL, Miller CS. Aspirin and bleeding in dentistry: an update and recommendations. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2007; **104**: 316–23.
17. Little JW, Miller CS, Henry RG, McIntosh BA. Antithrombotic agents: implications in dentistry. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2002; **93**: 544–51.
18. Lockhart PB, Gibson J, Pond SH, Leitch J. Dental management considerations for the patient with an acquired coagulopathy. Part 2: Coagulopathies from drugs. *Br Dent J* 2003; **95**: 495–501.
19. Marx RE, Johnson RP. Studies in the radiobiology of osteoradionecrosis and their clinical significance. *Oral Surg Oral Med Oral Pathol* 1987; **64**: 379–90.
20. Slagter KW, Raghoebar GM, Vissink A. Osteoporosis and edentulous jaws. *Int J Prosthodont* 2008; **21**: 19–26.
21. Holahan CM, Koka S, Kennel KA, Weaver AL, Assad DA, Regennitter FJ, Kademani D. Effect of osteoporotic status on the survival of titanium dental implants. *Int J Oral Maxillofac Implants* 2008; **23**: 905–10.
22. Roberts WE, Simmons KE, Garetto LP, DeCastro RA. Bone physiology and metabolism in dental implantology: risk factors for osteoporosis and other metabolic bone diseases. *Implant Dent* 1992; **1**: 11–21.
23. Isaacson TJ. Sublingual hematoma formation during immediate implant placement of mandibular endosseous implants. *J Am Dent Assoc* 2004; **135**: 566.
24. Piattelli A, Trisi P, Romasco N, Emanuelli M. Histological analysis of a screw implant retrieved from man: Influence

of early loading and primary stability. *J Oral Implantol* 1993; **19**: 303–6.
25. Jaffin RA, Berman C. The excessive loss of Brånemark fixtures in type IV bone: a year analysis. *J Periodontol* 1991; **62**: 2–4.
26. Bravi F, Bruschi GB, Ferrini F. A 10-year multicenter retrospective clinical study of 1715 implants placed with the edentulous ridge expansion technique. *Int J Periodont Restor Dent* 2007; **27**: 557–65.
27. Summers RB. The osteotome technique: Part 2. The ridge expansion osteotomy (REO) procedure. *Compendium* 1994; **15**: 422, 424, 426.
28. Truhlar RS, Farish SE, Scheitler LE, Morris HF, Ochi S. Bone quality and implant design-related outcomes through stage II surgical uncovering of spectra-system root form implants. *J Oral Maxillofac Surg* 1997; **55**: 46–54.
29. Landesberg R, Cozin M, Cremers S, Woo V, Kousteni S, Sinha S, *et al.* Inhibition of oral mucosal cell wound healing by bisphosphonates. *J Oral Maxillofac Surg* 2008; **66**: 839–47.
30. Grant BT, Amenedo C, Freeman K, Kraut RA. Outcomes of placing dental implants in patients taking oral bisphosphonates: a review of 115 cases. *J Oral Maxillofac Surg* 2008; **66**: 223–30.
31. Rizzoli R, Burlet N, Cahall D, Delmas PD, Eriksen EF, Felsenberg D, *et al*. Osteonecrosis of the jaw and bisphosphonate treatment for osteoporosis. *Bone* 2008; **42**: 841–7.
32. Wang HL, Weber D, McCauley LK. Effect of long-term oral bisphosphonates on implant wound healing: literature review and a case report. *J Periodontol* 2007; **78**: 584–94.
33. Kyrgidis A, Vahtsevanos K. Increased risk for bisphosphonate-related osteonecrosis of the jaws in patients wearing dentures could be attributable to impaired mucosal cell wound healing. *J Oral Maxillofac Surg* 2009; **67**: 1355–6.
34. O'Ryan FS, Khoury S, Liao W, Han MM, Hui RL, Baer D, *et al*. Intravenous bisphosphonate-related osteonecrosis of the jaw: bone scintigraphy as an early indicator. *J Oral Maxillofac Surg* 2009; **67**: 1363–72.
35. Takagi Y, Sumi Y, Harada A. Osteonecrosis associated with short-term oral administration of bisphosphonate. *J Prosthet Dent* 2009; **101**: 289–92.
36. Castells M. Rapid desensitization for hypersensitivity reactions to medications. *Immunol Allergy Clin North Am* 2009; **29**: 585–606.
37. Harper NJ, Dixon T, Dugué P, Edgar DM, Fay A, Gooi HC, *et al*., Working Party of the Association of Anaesthetists of Great Britain and Ireland. Suspected anaphylactic reactions associated with anaesthesia. *Anaesthesia* 2009; **64**: 199–211.
38. Bain CA, Moy PK. The association between the failure of dental implants and cigarette smoking. *Int J Oral Maxillofac Implants* 1993; **8**: 609–15.
39. de Bruyn H, Collaert B. The effect of smoking on early implant failure. *Clin Oral Implants Res* 1994; **5**: 260–4.
40. Haas R, Haimbock W, Mailath G, Watzek G. The relationship of smoking on peri-implant tissue: a retrospective study. *J Prosthet Dent* 1996; **76**: 592–6.
41. Jones JK, Triplett RG. The relationship of cigarette smoking to impaired intraoral wound healing: a review of evidence and implications for patient care. *J Oral Maxillofac Surg* 1992; **50**: 237–40.
42. Kan JY, Rungcharassaeng K, Lozada JL, Goodacre CJ. Effects of smoking on implant success in grafted maxillary sinuses. *J Prosthet Dent* 1999; **82**: 307–11.
43. Lambert PM, Morris HF, Ochi S. The influence of smoking on 3-year clinical success of osseointegrated dental implants. *Ann Periodontol* 2000; **5**: 79–89.
44. Zitzmann NU, Scharer P, Marinello CP. Factors influencing the success of GBR: smoking, timing of implant placement, implant location, bone quality and provisional restoration. *J Clin Periodontol* 1999; **26**: 673–82.
45. Bain CA. Smoking and implant failure benefits of a smoking cessation protocol. *Int J Oral Maxillofac Implants* 1996; **11**: 756–9.
46. DeLuca S, Habsha E, Zarb GA. The effect of smoking on osseointegrated dental implants. Part I: Implant survival. *Int J Prosthodont* 2006; **19**: 491–8.
47. Jemt T, Linden B, Lekholm U. Failures and complications in 127 consecutively placed fixed partial prostheses supported by Brånemark implants from prosthetic treatment to first annual check-up. *Int J Oral Maxillofac Implants* 1992; **7**: 40–4.
48. Taylor TD, Agar JR. Twenty years of progress in implant prosthodontics. *J Prosthet Dent* 2002; **88**: 89–95.
49. Walton JN, MacEntee MI. Problems with prostheses on implants: a retrospective study. *J Prosthet Dent* 1994; **71**: 283–8.
50. Isidor F. Loss of osseointegration caused by occlusal load of oral implants. A clinical and radiographic study in monkeys. *Clin Oral Implants Res* 1996; **7**: 143–52.
51. Miyata T, Kobayashi Y, Araki H, Motomura Y, Shin K. The influence of controlled occlusal overload on peri-implant tissue: a histologic study in monkeys. *Int J Oral Maxillofac Implants* 1998; **13**: 677–83.
52. Papalexiou V, Novaes AB Jr, Ribeiro RF, Muglia V, Oliveira RR. Influence of the interimplant distance on crestal bone resorption and bone density: a histomorphometric study in dogs. *J Periodontol* 2006; **77**: 614–21.
53. Teughels W, Merheb J, Quirynen M. Critical horizontal dimensions of interproximal and buccal bone around implants for optimal esthetic outcomes: a systematic review. *Clin Oral Implants Res* 2009; **20** (Suppl 4): 134–45.
54. Froum SJ, Cho SC, Cho YS, Elian N, Tarnow D. Narrow-diameter implants: a restorative option for limited interdental space. *Int J Periodont Restor Dent* 2007; **27**: 449–55.
55. Reddy MS, O'Neal SJ, Haigh S, Aponte-Wesson R, Geurs NC. Initial clinical efficacy of 3-mm implants immediately placed into function in conditions of limited spacing. *Int J Oral Maxillofac Implants* 2008; **23**: 281–8.
56. Agar JR, Cameron SM, Hughbanks JC, Parker MH. Cement removal from restorations luted to titanium abutments with simulated subgingival margins. *J Prosthet Dent* 1997; **78**: 43–7.
57. Pauletto N, Lahiffe BJ, Walton JN. Complications associated with excess cement around crowns on osseointegrated implants: a clinical report. *Int J Oral Maxillofac Implants* 1999; **14**: 865–8.
58. DeBoer J. Edentulous implants: overdenture versus fixed. *J Prosthet Dent* 1993; **69**: 386–90.

59. Desjardins RP. Prosthesis design for osseointegrated implants in the edentulous maxilla. I*nt J Oral Maxillofac Implants* 1992; **7**: 311–20.
60. Aykent F, Inan O, Ozyesil AG, Alptekin NO. A 1- to 12-year clinical evaluation of 106 endosseous implants supporting fixed and removable prostheses. *Int J Periodont Restor Dent* 2007; **27**: 358–67.
61. Jokstad A, Carr AB. What is the effect on outcomes of time-to-loading of a fixed or removable prosthesis placed on implant(s)? *Int J Oral Maxillofac Implants* 2007; **22** (Suppl): 19–48.
62. Batenburg RHK, Meijer HJA, Raghoebar GM, Vissink A. Treatment concept for mandibular overdentures supported by endosseous implants: a literature review. *Int J Oral Maxillofac Implants* 1998; **13**: 545–59.
63. Feine JS, Carlsson GE, Awad MA, Chehade A, Duncan WJ, Gizani S, *et al.* McGill 42 Consensus statement on overdentures. *Int J Oral Maxillofac Implants* 2002; **17**: 601–2.
64. Adell R, Eriksson B, Lekholm U, Brånemark PI, Jemt T. A long-term follow-up study of osseointegrated implants in the treatment of the totally edentulous jaw. *Int J Oral Maxillofac Implants* 1990; **5**: 347–59.
65. Albrektsson T, Zarb GA, Worthington P, Eriksson AR. The long-term efficacy of currently used dental implants: a review and proposed criteria for success. *Int J Oral Maxillofac Implants* 1986; **1**: 11–25.
66. Naert I, Quirijnen M, Theuniers G, Van Steenberghe D. Prosthetic aspects of osseointegrated fixtures supporting overdentures. A 4-year report. *J Prosthet Dent* 1991; **65**: 671–80.
67. Mericske-Stern R, Zarb GA. Overdentures: an alternative implant methodology for edentulous patients. *Int J Prosthodont* 1993; **6**: 203–8.
68. Napier ID. Reference doses for dental radiography. *Br Dent J* 1999; **186**: 392–6.
69. Tronje G, Eliasson S, Julin P, Welander U. Image distortion in rotational panoramic radiography. 11. Vertical distances. *Acta Radiol* 1981; **22**: 449–55.
70. Shabahang S, Bohsali K, Boyne PJ, Caplanis N, Lozada J, Torabinejad M. Effect of teeth with periradicular lesions on adjacent dental implants. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2003; **96**: 321–6.
71. Sussman HI, Moss SS. Localized osteomyelitis secondary to endodontic-implant pathosis. A case report. *J Periodontol* 1993; **64**: 306–10.
72. Mordenfeld A, Andersson L, Bergström B. Hemorrhage in the floor of the mouth during implant placement in the edentulous mandible: a case report. *Int J Oral Maxillofac Implants* 1997; **12**: 558–61.
73. Chen LC, Lundgren T, Hallström H, Cherel F. Comparison of different methods of assessing alveolar ridge dimensions prior to dental implant placement. *Periodontology* 2008; **79**: 401–5.
74. Schwarz MS, Rothman SL, Chafetz N, Rhodes M. Computed tomography in dental implantation surgery. *Dent Clin North Am* 1989; **33**: 555–97.
75. Williams MY, Mealey BL, Hallman WW. The role of computerized tomography in dental implantology. *Int J Oral Maxillofac Implants* 1992; **7**: 373–80.
76. Buser D, Dula K, Hirt HP, Schenk RK. Lateral ridge augmentation using autografts and barrier membranes: a clinical study with 40 partially edentulous patients. *Int J Oral Maxillofac Surg* 1996; **54**: 420–32.
77. Chiapasco M, Abati S, Romeo E, Vogel G. Clinical outcome of autogenous bone blocks or guided bone regeneration with e-PTFE membranes for the reconstruction of narrow edentulous ridges. *Clin Oral Implants Res* 1999; **10**: 278–88.
78. Kan JY, Rungcharassaeng K, Umezu K, Kois JC. Dimensions of peri-implant mucosa: an evaluation of maxillary anterior single implants in humans. *J Periodontol* 2003; **74**: 557–62.
79. Weisgold A. Contours of the full crown restoration. *Alpha Omegan* 1977; **70**: 77–89.
80. Araujo MG, Sukekava F, Wennstrom JL, Lindhe J. Ridge alterations following implant placement in fresh extraction sockets: an experimental study in the dog. *J Clin Periodontol* 2005; **2**: 645–52.
81. Cornelini R, Cangini F, Covani U, Wilson TG Jr. Immediate restoration of implants placed into fresh extraction sockets for single-tooth replacement: a prospective clinical study. *Int J Periodont Restor Dent* 2005; **25**: 439–47.
82. Covani U, Bortolaia C, Barone A, Sbordone L. Buccolingual crestal bone changes after immediate and delayed implant placement. *J Periodontol* 2004; **75**: 1605–12.
83. Olsson M, Lindhe J. Periodontal characteristics in individuals with varying form of the upper central incisors. *J Clin Periodontol* 1991; **18**: 78–82.
84. Seibert J, Lindhe J. Esthetics in periodontal therapy. In: Lindhe J, ed. *Textbook of clinical periodontology*, 3rd edn. Copenhagen: Munksgaard, 1997: 647–81.
85. Chen ST, Wilson TG Jr, Hammerle CH. Immediate or early placement of implants following tooth extraction: review of biologic basis, clinical procedures, and outcomes. *Int J Oral Maxillofac Implants* 2004; **19** (Suppl): 12–25.
86. Kois JC, Kan JYK. Predictable peri-implant gingival anesthetics: surgical and prosthodontic rationales. *Pract Periodont Aesthet Dent* 2001; **13**: 691–8.
87. Bahat O, Handelsman M. Use of wide implants and double implants in the posterior jaw: a clinical report. *Int J Oral Maxillofac Implants* 1996; **11**: 379–86.
88. Anner R, Better H, Chaushu G. The clinical effectiveness of 6 mm diameter implants. *J Periodont* 2005; **76**: 1013–15.
89. Ivanoff CJ, Grondahl K, Sennerby L, Bergstrom C, Lekholm U. Influence of variations in implant diameters: a 3- to 5-year retrospective clinical report. *Int J Oral Maxillofac Implants* 1999; **14**: 173–80.
90. Karoussis IK, Müller S, Salvi GE, Heitz-Mayfield LJ, Brägger U, Lang NP. Association between periodontal and peri-implant conditions: a 10-year prospective study. *Clin Oral Implants Res* 2004; **15**: 1–7.
91. Mombelli A, Van Oosten MAC, Schürch E, Lang NP. The microbiota associated with successful or failing osseointegrated titanium implants. *Oral Microbiol Immunol* 1987; **2**: 145–51.
92. Bouri A Jr, Bissada N, Al-Zahrani MS, Faddoul F, Nouneh I. Width of keratinized gingiva and the health status of the supporting tissues around dental implants. *Int J Oral Maxillofac Implants* 2008; **23**: 323–6.

93. Warrer K, Buser D, Lang NP, Karring T. Plaque-induced peri-implantitis in the presence or absence of keratinized mucosa. An experimental study in monkeys. *Clin Oral Implants Res* 1995; **6**: 131–8.
94. Glauser R, Schüpbach P, Gottlow J, Hämmerle CH. Periimplant soft tissue barrier at experimental one-piece mini-implants with different surface topography in humans: a light-microscopic overview and histometric analysis. *Clin Implant Dent Relat Res* 2005; **7** (Suppl 1): S44–51.
95. Zigdon H, Machtei EE. The dimensions of keratinized mucosa around implants affect clinical and immunological parameters. *Clin Oral Implants Res* 2008; **19**: 387–92.
96. Bollen CM, Papaioanno W, Van Eldere J, Schepers E, Quirynen M, van Steenberghe D. The influence of abutment surface roughness on plaque accumulation and periimplant mucositis. *Clin Oral Implants Res* 1996; **7**: 201–11.
97. Khoury F, Happe A. Soft tissue management in oral implantology: a review of surgical techniques for shaping an esthetic and functional peri-implant soft tissue structure. *Quintessence Int* 2000; **7**: 483–99.
98. Price RB, Price DE. Esthetic restoration of a single-tooth dental implant using a subepithelial connective tissue graft: a case report with 3-year follow-up. *Int J Periodont Restor Dent* 1999; **1**: 92–101.
99. Reed BE, Polson AM. Relationship between bitewing and periapical radiographs in assessing crestal alveolar bone levels. *J Periodontol* 1984; **55**: 22–7.
100. Ritto FG, Medeiros PJ, de Oliveira Mussel RL, de-Sá-Silva E. Rehabilitation of an adolescent with ectodermal dysplasia. Two-stage orthognathic, graft, and implant surgery: case report. *Implant Dent* 2009; **18**: 311–15.
101. Sewerin IP, Gotfredsen K, Stoltze K. Accuracy of radiographic diagnosis of periimplant radiolucencies: an in vitro experiment. *Clin Oral Implants Res* 1997; **8**: 299–304.
102. Schaffer MD, Junuaz DA, Haggerty PC. The effect of periradicular endodontic pathosis on the apical region of adjacent implants. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1998; **86**: 578–81.
103. Mecall RA, Rosenfeld AL. The influence of residual ridge resorption patterns on implant fixture placement and tooth position. 2. Presurgical determination of prosthesis type and design. *Int J Periodont Restor Dent* 1992; **12**: 32–51.
104. Lang NP, Wilson TG, Corbet EF. Biological complications with dental implants: their prevention, diagnosis and treatment. *Clin Oral Implant Res* 2000: **11** (Suppl): 146–55.
105. Lazzara RJ. Immediate implant placement into extraction sites: surgical and restorative advantages. *Int J Periodont Restor Dent* 1989; **9**: 332–43.
106. Schnitman P, Wöhrle P, Rubenstein J, DaSilva J, Wang N. Ten-year results for Brånemark implants immediately loaded with fixed prostheses at implant placement. *Int J Oral Maxillofac Implants* 1997; **12**: 495–503.
107. Bergendal B. Prosthetic habilitation of a young patient with hypohidrotic ectodermal dysplasia and oligodontia: a case report of 20 years of treatment. *Int J Prosthodont* 2001; **14**: 471–9.
108. Engelman MJ, Sorensen JA, Moy P. Optimum placement of osseointegrated implants. *J Prosthet Dent* 1988; **59**: 467–43.
109. Misch CE. *Contemporary implant dentistry*, 2nd edn. St Louis, MO: Mosby, 1999: 97–9.
110. ten Bruggenkate CM, Krekeler G, Kraaijenhagen HA, Foitzik C, Oosterbeek HS. Hemorrhage of the floor of the mouth resulting from lingual perforation during implant placement: a clinical report. *Int J Oral Maxillofac Implants* 1993; **8**: 329–34.
111. Asvanund C, Morgano SM. Restoration of unfavorably positioned implants for a partially endentulous patient by using an overdenture retained with a milled bar and attachments: a clinical report. *J Prosthet Dent* 2004; **91**: 6–10.
112. Tanaka T, Shaw P. Anatomy for implant dentistry: mandible. *Quintessence Dent Implantol* 1995; **2**: 10–20.
113. Hofschneider U, Tepper G, Gahleitner A, Ulm C. Assessment of the blood supply to the mental region for reduction of bleeding complications during implant surgery in the interforaminal region. *Int J Oral Maxillofac Implants* 1999; **14**: 379–83.
114. Morris HF, Ochi S, Spray JR, Olson JW. Periodontal-type measurements associated with hydroxyapatite-coated and non-HA-coated implants: uncovering to 36 months. *Ann Periodontol* 2000; **5**: 56–67.
115. Priest GF, Lindke L. Gingival-colored porcelain for implant-supported prostheses in the aesthetic zone. *Pract Periodontics Aesthet Dent* 1998; **10**: 1231–40.
116. Zalkind M, Hochman N. Alternative method of conservative esthetic treatment for gingival recession. *J Prosthet Dent* 1997; **77**: 561–3.
117. Cardash HS, Gansherowitz J, Serebro L, Marshak B. The role of study casts in prosthodontic treatment. *Quintessence Int* 1985; **4**: 263–6.
118. Pruden WH II. The role of study casts in diagnosis and treatment planning. *J Prosthet Dent* 1960; **10**: 707–10.
119. Machtei E. The effect of membrane exposure on the outcome of regenerative procedures in humans: a meta-analysis. *J Periodontol* 2001; **72**: 512–16.
120. Pesun IJ, Gardner FM. Fabrication of a guide for radiographic evaluation and surgical placement of implants. *J Prosthet Dent* 1995; **73**: 548–52.
121. Thüer U, Ingervall B. Pressure from the lips on the teeth and malocclusion. *Am J Orthodont Dentofac Orthop* 1986; **90**: 234–42.
122. Verardi S, Simion M. Management of the exposure of e-PTFE membranes in guided bone regeneration. *Pract Proced Aesthet Dent* 2007; **19**: 111–17.
123. Botticelli D, Persson LG, Lindhe J, Berglundh T. Bone tissue formation adjacent to implants placed in fresh extraction sockets: an experimental study in dogs. *Clin Oral Implant Res* 2006; **17**: 351–8.
124. Cardaropoli G, Araujo M, Hayacibara R, Sukekava F, Lindhe J. Healing of extraction sockets and surgically produced – augmented and non-augmented – defects in the alveolar ridge. An experimental study in the dog. *J Clin Periodontol* 2005; **32**: 435–40.
125. Abrahamsson I, Berglundh T, Moon IS, Lindhe J. Periimplant tissues at submerged and nonsubmerged titanium implants. *J Clin Periodontol* 1999; **26**: 600–7.

126. Hermann JS, Buser D, Schenk RK, Schoolfield JD, Cochran DL. Biologic width around one- and two-piece titanium implants. A histometric evaluation of unloaded nonsubmerged and submerged implants in the canine mandible. *Clin Oral Implant Res* 2001; **12**: 559–71.
127. Werbitt MJ, Goldberg PV. The immediate implant: bone preservation and bone regeneration. *Int J Periodont Restor Dent* 1992; **12**: 206–17.
128. Brunski JB. Biomechanical factors affecting the bone–dental implant interface. *Clin Mater* 1992; **3**: 153–201.
129. Schwartz-Arad D, Samet N, Mamlider A. Smoking and complications of endosseous dental implants. *J Periodontol* 2002; **73**: 153–7.
130. Terzioglu H, Akkaya M, Ozan O. The use of a computerized tomography-based software program with a flapless surgical technique in implant dentistry: a case report. *Int J Oral Maxillofac Implants* 2009; **24**: 137–42.
131. Quirynen M, Papaioannou W, van Steenberghe D. Intraoral transmission and the colonization of oral hard surfaces. *J Periodontol* 1996; **67**: 986–93.
132. Tsuzuki T, Matsuura T, Kido H, Ishikawa M, Ukon S, Sato H. New fabrication system for dental implant surgical stents: time-saving laboratory technique using a light-curing resin and transparent artificial teeth. *Clin Implant Dent Relat Res* 2001; **3**: 107–10.
133. Becker CM, Kaiser DA. Surgical guide for dental implant placement. *J Prosthet Dent* 2000; **83**: 248–51.
134. Kopp KC, Koslow AH, Abdo OS. Predictable implant placement with a diagnostic/surgical template and advanced radiographic imaging. *J Prosthet Dent* 2003; **89**: 611–15.
135. Rosenfeld AL, Mecall RA. The use of interactive computed tomography to predict the esthetic and functional demands of implant-supported prostheses. *Compend Contin Educ Dent* 1996; **17**: 1125–8, 1130–2.
136. Dula K, Mini R, van der Stelt PF, Buser D. The radiographic assessment of implant patients: decision-making criteria. *Int J Oral Maxillofac Implants* 2001; **16**: 80–9.
137. Chiche GJ, Block MS, Pinault A. Implant surgical template for partially edentulous patients. *Int J Oral Maxillofac Implants* 1989; **4**: 289–92.
138. Solow RA. Simplified radiographic–surgical template for placement of multiple, parallel implants. *J Prosthet Dent* 2001; **85**: 26–9.
139. Wanschitz F, Birkfellner W, Watzinger F, Schopper C, Patruta S, Kainberger F, *et al.* Evaluation of accuracy of computer-aided intraoperative positioning of endosseous oral implants in the edentulous mandible. *Clin Oral Implant Res* 2002; **13**: 59–64.
140. Proffit WR. Equilibrium theory revisited: factors influencing position of the teeth. *Angle Orthod* 1978; **48**: 175–86.
141. Jivraj SA, Corrado P, Chee WW. An interdisciplinary approach to treatment planning in implant dentistry. *J Calif Dent Assoc* 2005; **33**: 293–300.
142. Lum MG, Shah KC. A multidisciplinary approach to treatment planning the single-implant restoration: interdisciplinary coordination. *J Calif Dent Assoc* 2008; **36**: 837–48.
143. Augthun M, Conrads G. Microbial findings of deep periimplant bone defects. *Int J Oral Maxillofac Implants* 1997; **12**: 106–12.
144. van Steenberghe D, Jacobs R, Desnyder M, Maffei G, Quirynen M. The relative impact of local and endogenous patient-related factors on implant failure up to the abutment stage. *Clin Oral Implant Res* 2002; **13**: 617–22.
145. Wang HL, Al-Shammari K. HVC ridge deficiency classification: a therapeutically oriented classification. *Int J Periodont Restor Dent* 2002; 22: 335–43.
146. Blahout RM, Hienz S, Solar P, Matejka MH, Ulm CW. Quantification of bone resorption in the interforaminal region of the atrophic mandible. *Int J Oral Maxillofac Implants* 2007; **22**: 609–15.
147. Chappuis V, Suter VG, Bornstein MM. Displacement of a dental implant into the maxillary sinus: report of an unusual complication when performing staged sinus floor elevation procedures. *Int J Periodont Restor Dent* 2009; **29**: 81–7.
148. Raghoebar GM, Vissink A. Treatment for an endosseous implant migrated into the maxillary sinus not causing maxillary sinusitis: case report. *Int J Oral Maxillofac Implants* 2003; **18**(5): 74.

Chapter 4

Implant complications associated with two- and three-dimensional diagnostic imaging technologies

Scott D. Ganz DMD

Introduction

The clinical application of dental implants has evolved into a predictable treatment alternative for patients who are missing teeth (1–3). The high success rates have been attributed to specific improvements related to surgical armamentarium, implant design, surface treatments of titanium, the mechanics of the implant-to-abutment connection, prosthetic protocols and associated components, soft- and hard-tissue grafting, immediate and delayed protocols, and soft-tissue management. Concurrent to the progress generated through implant manufacturers and clinical research were significant developments in diagnostic imaging technologies and interactive treatment planning software. Incorporation of evolving technologies will continue to have far-reaching implications on the future of implant reconstruction.

The ability to assess patient anatomy has traditionally been limited to two-dimensional (2D) periapical or panoramic radiography, despite their inherent limitations (4–11). Radiographic distortions or clinical misinterpretation can result in serious complications. These complications can include but are not limited to damage of adjacent teeth; encroachment or perforation of vital structures including the inferior alveolar nerve, the maxillary sinus, the floor of the nose, and the facial or lingual cortical plates (12–25). In addition, implants may be placed in unrestorable positions, implants may fail to integrate owing to faulty diagnosis, implants may be placed too close together, or they may be too wide for the receptor site, resulting in prosthetic and soft-tissue complications.

Standard periapical or panoramic radiographs have been the industry standard in 2D imaging for dental implants since the inception of dental implants and the osseointegration phenomenon. While excellent modalities for detecting dental caries and periodontal disease, there are inherent limitations which can result in complications when assessing dental implant receptor sites, and interpreting spatial relationships of vital anatomic landmarks (26, 27). Two-dimensional periapical and panoramic radiographs cannot accurately inform clinicians of the quality of bone, the density of bone, the thickness of the cortical plates, the width of the alveolar bone, the true proximity to adjacent roots, the inferior alveolar nerve, the mental foramen, and the maxillary sinus. Periapical and panoramic 2D radiographs also contain inherent distortion factors or superimposition of anatomic structures which complicate diagnosis when this distortion is unknown or improperly calibrated. An early study which compared periapical, panoramic, and computed tomographic (CT) scan imaging modalities found significant distortion in conventional 2D imaging, with almost no distortion with medical grade CT (4). In addition, many clinicians fail to calibrate panoramic machines regularly and do not take into consideration the horizontal and vertical distortions that are present (28). Laster concluded that, "Panoramic radiographs should be used with caution in making absolute measurements or relative comparisons. Even when internal fiducial calibration for image distortion of anatomy is used, measurements such as those assessing posterior mandibular facial symmetry may be unreliable" (28). Clinicians who rely solely on 2D imaging technologies may be disappointed in their treatment outcomes.

Three-dimensional (3D) data gathered from CT or cone beam computed tomographic (CBCT) scans of the mandible or maxilla can be extremely revealing. Virtual reconstruction using specific software applications can aid the clinician in evaluating patient-specific anatomy, interpreting bony structures, nerves, vessels, and possible implant receptor sites in relation to the proposed implant placement. The ability to assimilate the information presented by CT-derived data through diagnostic and treatment planning software has the potential to diminish implant complications greatly (8, 26–33).

Case 1: Complications due to scanographic templates

Etiology

To facilitate an understanding of the relationship of the planned restoration to the underlying bone, it has been

recommended that presurgical prosthetic planning commence with the fabrication of a radiopaque scanning template. For a fully edentulous presentation the author believes that a properly constructed scanographic template is an invaluable aid. The template can be fabricated by the dental laboratory technician through the duplication of a diagnostic wax-up, or the patient's existing denture. The patient will then wear the template at the time the scan is taken. Complications can occur if the template is not properly fabricated or does not fit precisely, leading to movement during the scanning process. In addition, if the patient's existing denture does not represent the proper tooth position or the wrong plane of occlusion, the location of the subsequently placed implants will be incorrect, even though a CT-derived surgical template may be constructed and utilized. In a study of mandibular positioning to determine whether a correct guiding plane is necessary to position the jaw accurately to the CT scanning plane, Kim *et al.* concluded that, "Communication among the surgeon, radiologist, and radiologic technician is very important, and it is necessary to have a guiding protocol for implant patient positioning in the CT gantry" (34). Therefore, the surgical template is only as good as the scanning appliance and the final plan. As the author states, "It's not the SCAN, it's the PLAN®".

Prevention

The maxillary and mandibular complex can be scanned together if the field of view is large enough. Medical grade CT scans have this ability, as do certain CBCT machines. When contemplating full mouth reconstruction, the ability to scan both arches may be desirable to gain a total overview of the maxillomandibular complex (Fig. 4.1a). The maxillary arch was scanned with a barium

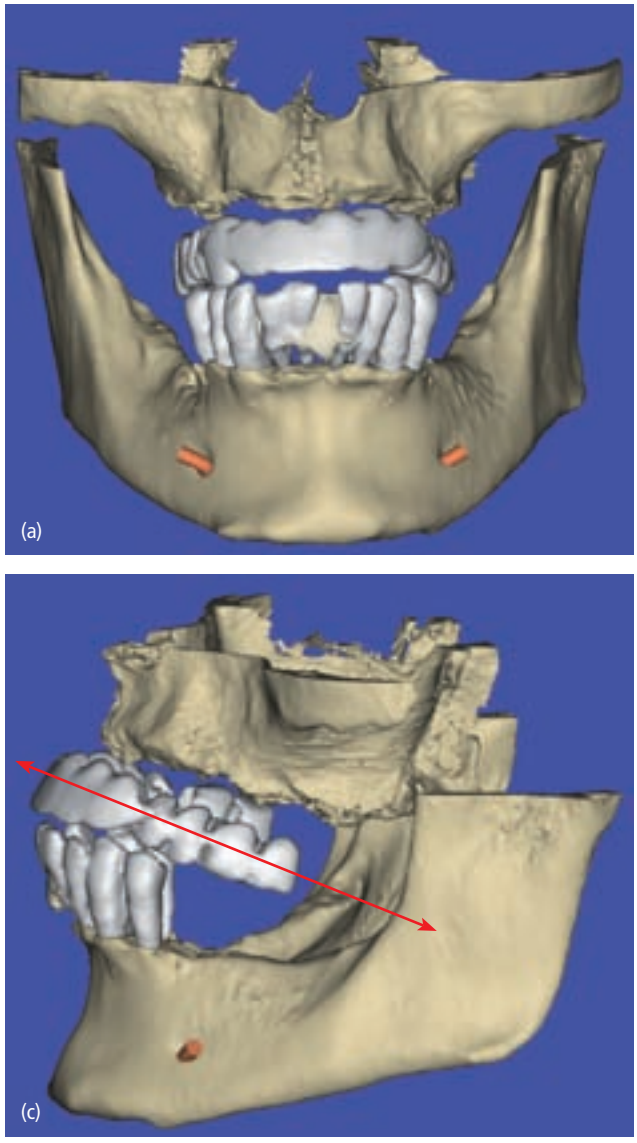
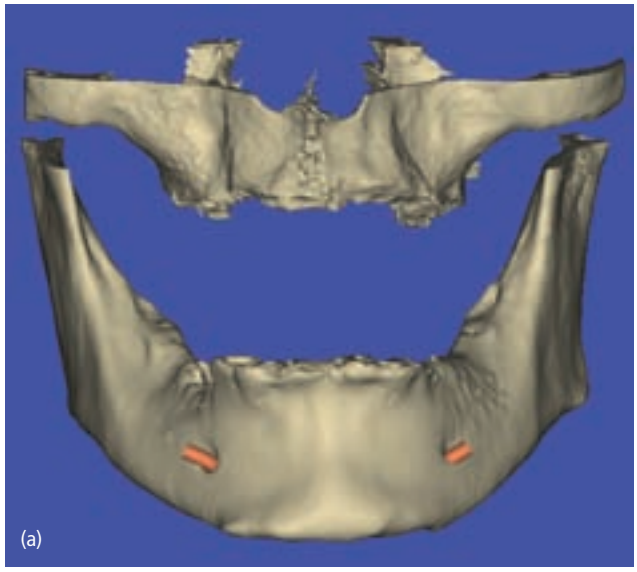


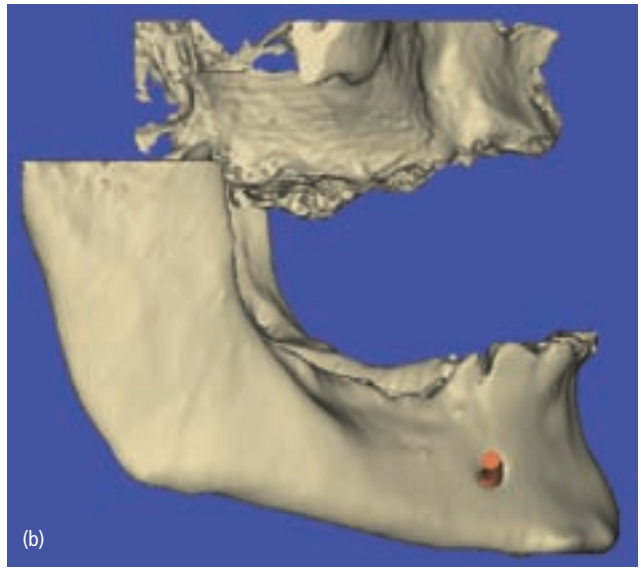
Fig. 4.1 (a) CBCT scan of a patient with a radiopaque scanning appliance generated from duplication of existing maxillary complete denture. (b) The plane of occlusion was incorrect and off-angle. (c) If this scan appliance were used to plan implants, the resulting restoration would be flawed.

sulfate, radiopaque duplicate of the patient's denture, against the remaining mandibular natural teeth. The right lateral view reveals a flaw in the planning process as it is apparent that the existing maxillary denture's plane of occlusion was off-angle (Fig. 4.1b). The left lateral view reveals a similar picture of the maxillary denture occluding with the remaining mandibular teeth (Fig. 4.1c). If the implants were planned to coincide with the positioning of the maxillary denture, the resulting reconstruction would be flawed.

Treatment

Fortunately, advanced software applications continue to evolve which can help us to understand the existing occlusal relationships, as well as establish new maxillomandibular relationships. The first step would be to virtually remove the radiopaque maxillary template, and virtually "extract" the natural mandibular dentition (Fig. 4.2a). The maxillomandibular complex can be fully appreciated in Fig. 4.2(b, c). To re-establish a proper plane of occlusion, a virtual wax-up can be created. The virtual tooth position can be superimposed over the radiopaque denture template to appreciate the difference (Fig. 4.3a, b). When the maxillary denture is removed from view the new virtual occlusion can be inspected (Fig. 4.3c). The virtual occlusion can be seen from the left and right lateral sides (Fig. 4.4a, b). While the software applications have advanced virtual methods to re-establish occlusion, the actual implementation of this new maxillomandibular relationship for implant planning is still in its infancy. However, the visualization of the virtual occlusion is useful to understand and determine whether implants can be placed within the envelope of the tooth position (Fig. 4.4c). If implants can be placed, the type of prosthesis can be determined, i.e. fixed-





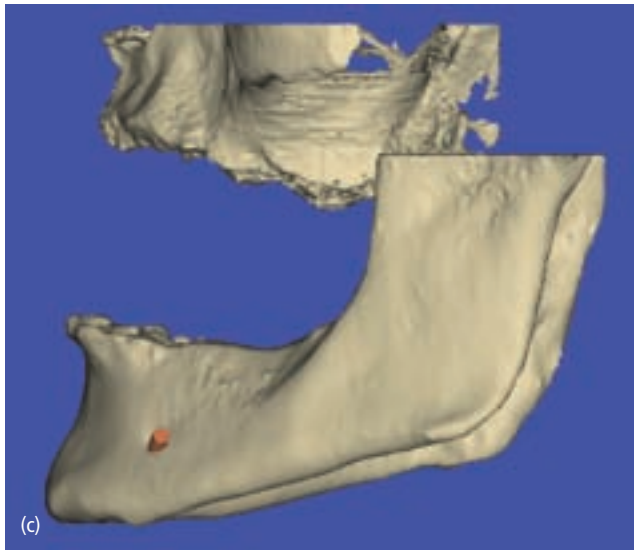


Fig. 4.2 (a) Large field of view CT or CBCT scans can capture both the maxilla and mandible. (b, c) The relationship between arches can be clearly visualized with the dentition removed.

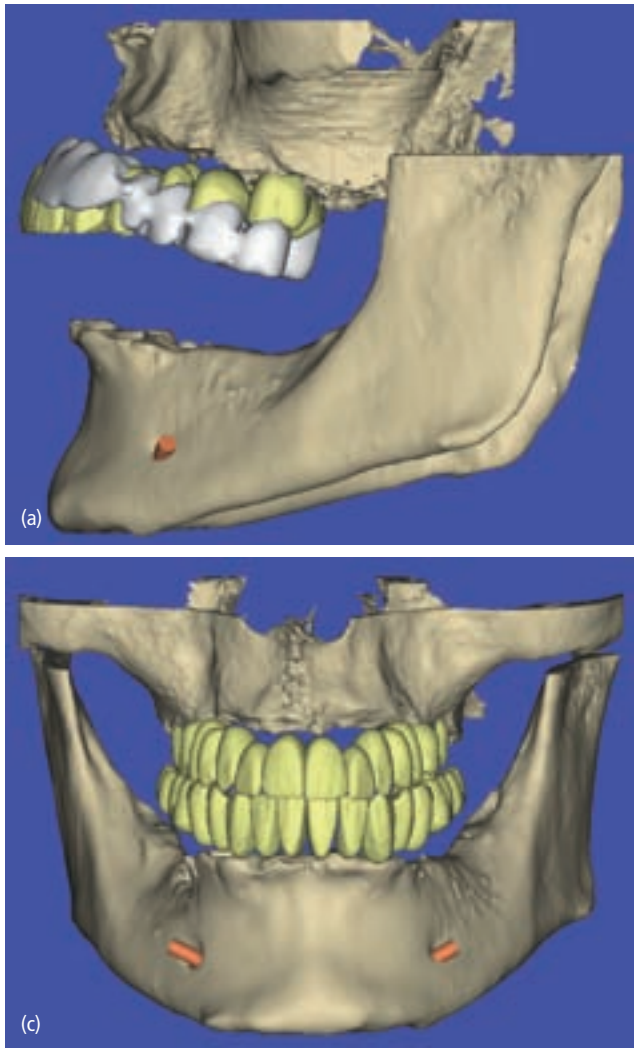


Fig. 4.3 (a, b) Virtual teeth created via treatment planning software overlay the maxillary scanning appliance to illustrate the use of a virtual occlusion. These innovative tools are helpful in re-establishing correct occlusal relationships, for both arches (c).

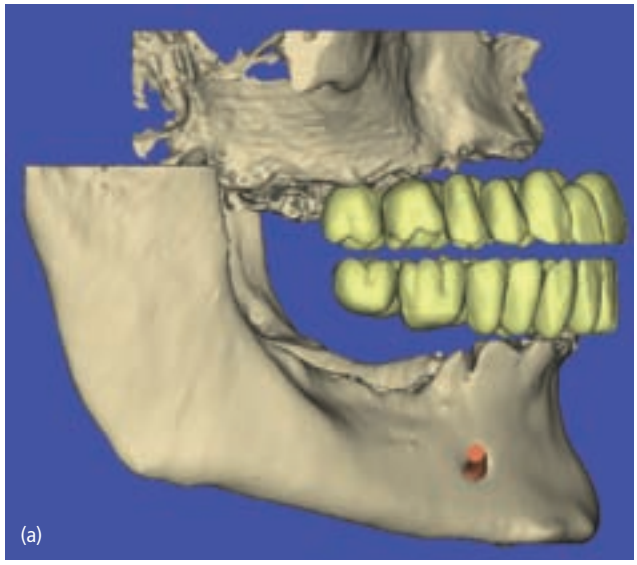
hybrid, screw-retained or cementable restoration, or an implant-supported overdenture. Currently, there is no substitute for a properly constructed radiopaque scanning prosthesis which represents the ideal tooth position (35–40).

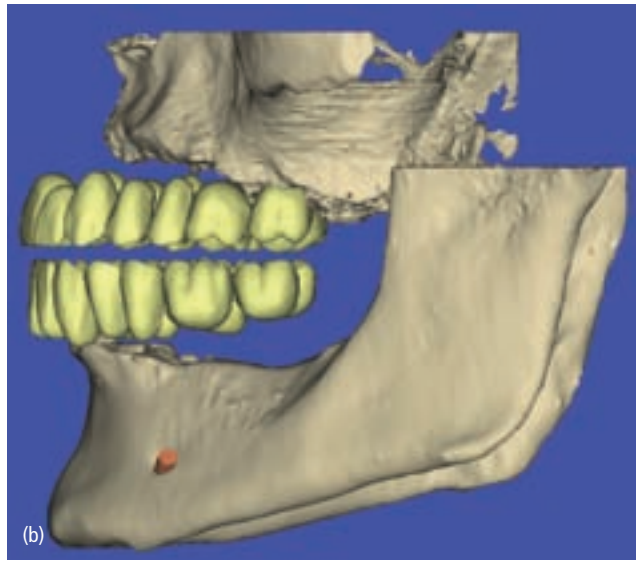
Case 2: Long-term complications due to nerve perforation

A 64-year-old woman presented with pain and swelling in the mandibular left quadrant which was intermittent and associated with vertical movement of the existing full-arch fixed prosthesis supported by implants and natural teeth. The panoramic radiograph revealed three remaining natural teeth in the left posterior quadrant each having had root canal therapy and post fabrication to support the left-side reconstruction (Fig. 4.5). The fixed prosthesis was supported on the left side with a universal-type endosseous blade implant, and supported at the midline with a blade implant. The left-side prosthetic design exhibited a posterior molar cantilever, decay around all gingival marginal areas, and radiographic evidence of fractured roots. The surrounding soft tissue was swollen and edematous.

Etiology

Significant dental history revealed that two endosseous blade form implants, one in the posterior right mandible and the other in the mid-symphyseal region, had been placed approximately 17 years previously. Subsequently and immediately following the placement of the right-side implant, the patient experienced profound paresthesia of the right lip and cheek area. Over a period of several months the patient was referred to several oral surgeons and neurologists for consultation, and elected not to proceed with further treatment or removal of the offending implant. The cheek numbness resolved 100%; however, a significant area of the lip did not recover. The patient acclimated to the diminished sensory function.





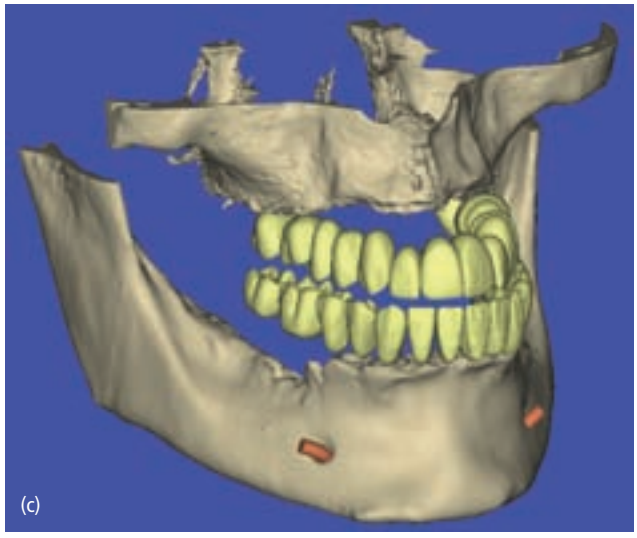


Fig. 4.4 (a, b) Visualization of the desired tooth position in relationship to the underlying bone is helpful in planning for implant placement (left and right), and (c) determining whether implants can be placed within the envelope of the tooth position.

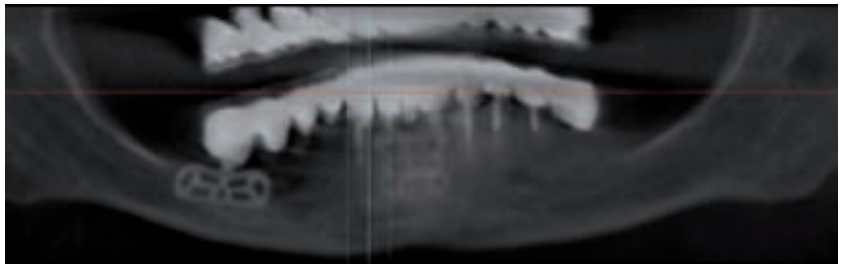


Fig. 4.5 Panoramic radiograph revealing three remaining natural teeth in the left posterior quadrant, each having had root canal therapy and post fabrication which exhibited swelling intraorally. Note the two endosseous blade form implants.

Prevention

As part of the diagnostic work-up a CBCT scan was advised, and performed. The cross-sectional reconstructions of the left blade form implant illustrate the buccal placement within the posterior mandible. The relative density of the buccal and lingual cortical bone, as well as the intermedullary bone, can be inspected (Fig. 4.6a). A significant radiolucent around a great portion of the implant can be evaluated. The mandibular midline cross-sectional slice revealed part of the blade form implant located facial to the ridge and bulk volume of existing bone (Fig. 4.6b). As previously described, there are various vessels (see arrow) that reside in this region which can be visualized and identified through advanced imaging capabilities. The left-side blade form implant was also isolated in the cross-sectional view to reveal buccal placement in relation to the facial–lingual width

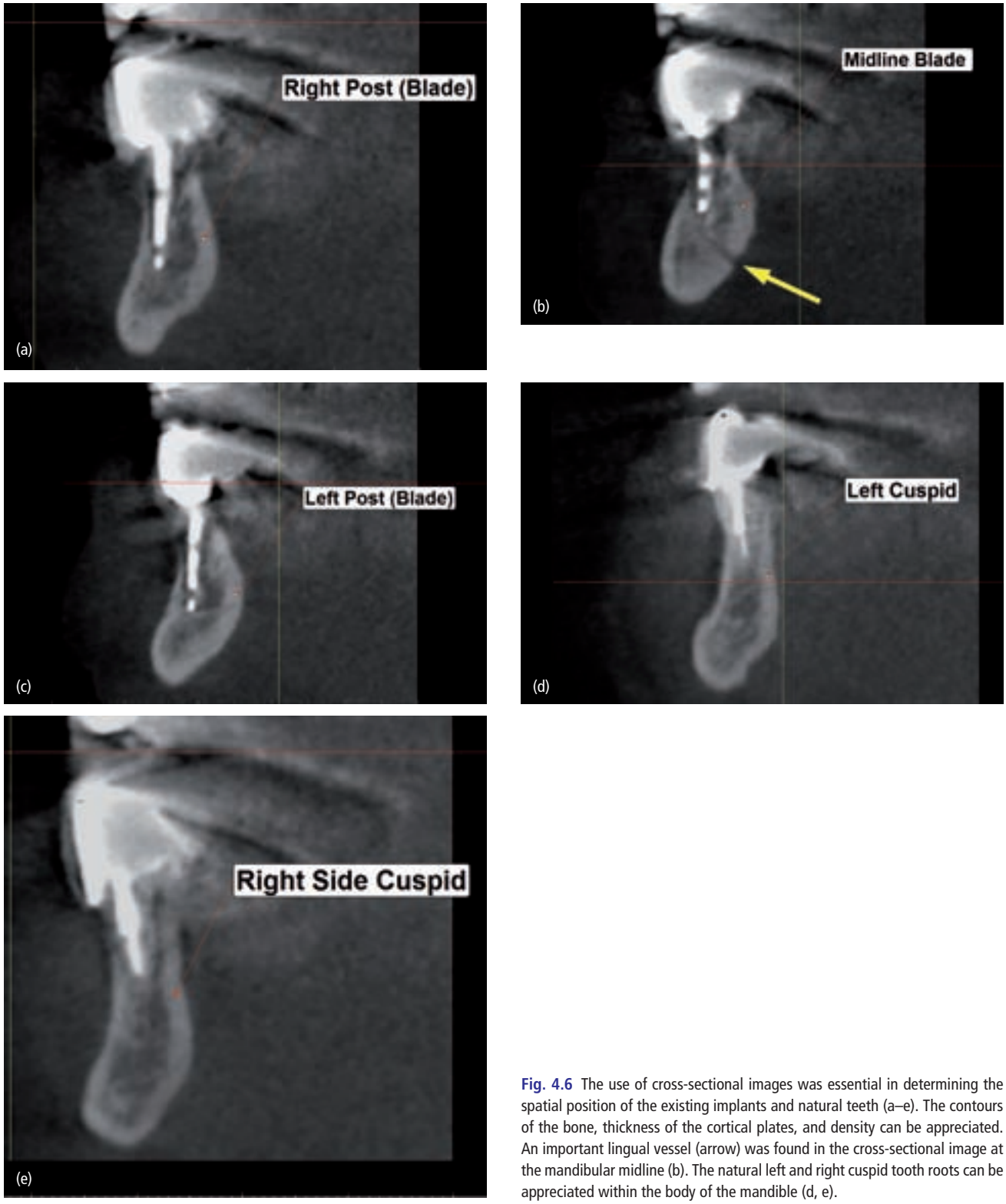


Fig. 4.6 The use of cross-sectional images was essential in determining the spatial position of the existing implants and natural teeth (a–e). The contours of the bone, thickness of the cortical plates, and density can be appreciated. An important lingual vessel (arrow) was found in the cross-sectional image at the mandibular midline (b). The natural left and right cuspid tooth roots can be appreciated within the body of the mandible (d, e).

of the mandibular ridge (Fig. 4.6c). The thin facial cortical plate of bone in proximity to the coronal aspect of the implant can be directly visualized and compared with the lingual cortical bone thickness. The natural left and right cuspid tooth roots can be fully appreciated within the body of the mandible through cross-sectional imaging revealing previous root canal therapy and post and core restorations (Fig. 4.6d, e).

The axial reconstructions are important for additional inspection of the mandible from a different vantage point revealing the embedded blade form implant in relation to the residual bone and path of the inferior alveolar nerve (Fig. 4.7). The thin lingual cortical plate is evident. An inspection of the mandibular symphysis reveals the facial position of the embedded blade implant. Using advanced interactive software applications the path of the nerve was accurately traced; however, the integrity of the nerve cannot be determined from these tracings. The path of the inferior nerve, when traced, clearly demonstrates the proximity to the position of the blade form placed in the posterior right mandible. In fact, the blade implant sliced directly through the nerve, causing immediate paresthesia. Returning to the cross-sections, portions of the right blade form implant can be clearly seen penetrating the posterior alveolar bone in sequential slices (Fig. 4.8a–c). Moving toward the most posterior aspect of the mandible part of the lingual placement of the blade extension avoided that portion of the nerve on the lingual aspect of the mandible (Fig. 4.8d). Unfortunately, the damage had already been done by the anterior extension of the body of the implant.

The reconstructed 3D view of the mandible with the existing fixed prosthesis can be seen in Fig. 4.9(a). Through advanced segmentation techniques the radiopaque ceramometal restorations were modified within the software to appear white, and the mandible's color was chosen to resemble natural bone as an aid in the process of diagnosis and treatment planning. The ability to segment out the different elements of the patient anatomy allows for unprecedented evaluation. "Selective transparency", as defined by the author, allows the clinician to choose which element's opacity will be modified to allow for inspection of the underlying anatomic presentation (41–43). The specific shape of the anterior blade implant with the tell-tale perforations and double abutment head design can be clearly visualized when the outer mandibular cortical bone is rendered semi-transparent (Fig. 4.9b). The side view of the right mandible illustrates the pre-existing long span and the right mental foramen (Fig. 4.10a). Selective transparency further reveals the entire shape of the buried blade form implant, the cuspid root on the right side and, when rotated, the remaining left-side tooth roots (Fig. 4.10b, c). The frontal view reveals the size of the implant which was placed within the midline (Fig. 4.10d). The bone can be removed entirely to reveal the prosthesis, the blade implants, and the path of the bilateral inferior alveolar nerves (Fig. 4.10e). Tracing the canal through the right mandible reveals the path of the nerve (Fig. 4.11a). The blade form implant clearly perforated through the nerve causing permanent paresthesia (Fig. 4.11b). Advanced imaging technologies can aid clinicians in their understanding of how vital anatomy could be injured. The combination of CT/CBCT and interactive treatment planning software provides accurate and essential information which could prevent iatrogenic damage from occurring if used in the preoperative planning.

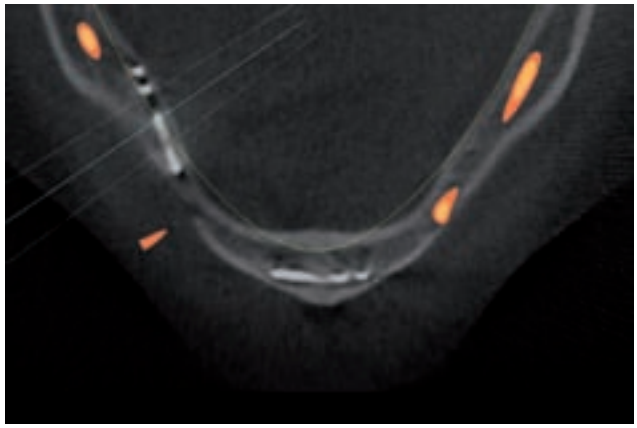


Fig. 4.7 The axial view helped to identify the discontinuity of the buccal cortical plate indicating the mental foramina, location of the two implants, and path of the inferior alveolar nerve.

Treatment

After careful evaluation of the 3D data, an appropriate treatment plan was developed to replace the failing ceramometal bridge. The remaining natural teeth and the mobile anterior blade implant had a hopeless prognosis, and would have to be removed. The patient wanted to maintain a fixed-type prosthesis. Using the CBCT scan data, the residual bone was evaluated for potential implant receptor sites. Favorable sites were found in five locations which provided adequate surrounding bone volume to allow for implant fixation. The cross-sectional images reveal five realistic implant simulations placed between the two mental foramina (Fig. 4.12a–e). Once the implant receptor sites have been carefully identified in the cross-sectional images, final confirmations can be made using the 3D reconstruction of the mandible. Using advanced segmentation, the existing tooth roots, blade implants, and prosthesis can be removed to show the implants with the abutment projections in yellow (Fig. 4.13a). The irregular and thin bony topography of the anterior symphysis was found to be unfavorable for implant placement. The ability to section the bone virtually allowed for the anterior mandible to be "leveled" so that the implants could be placed within adequate bone width, while maintaining an even vertical placement (Fig. 4.13b) (44). Further manipulation shows how the implants were placed in a parallel orientation between the two mental foramina and at the same vertical height (Fig. 4.14a). In addition to planning for proper implant placement, the design of the surgical template was

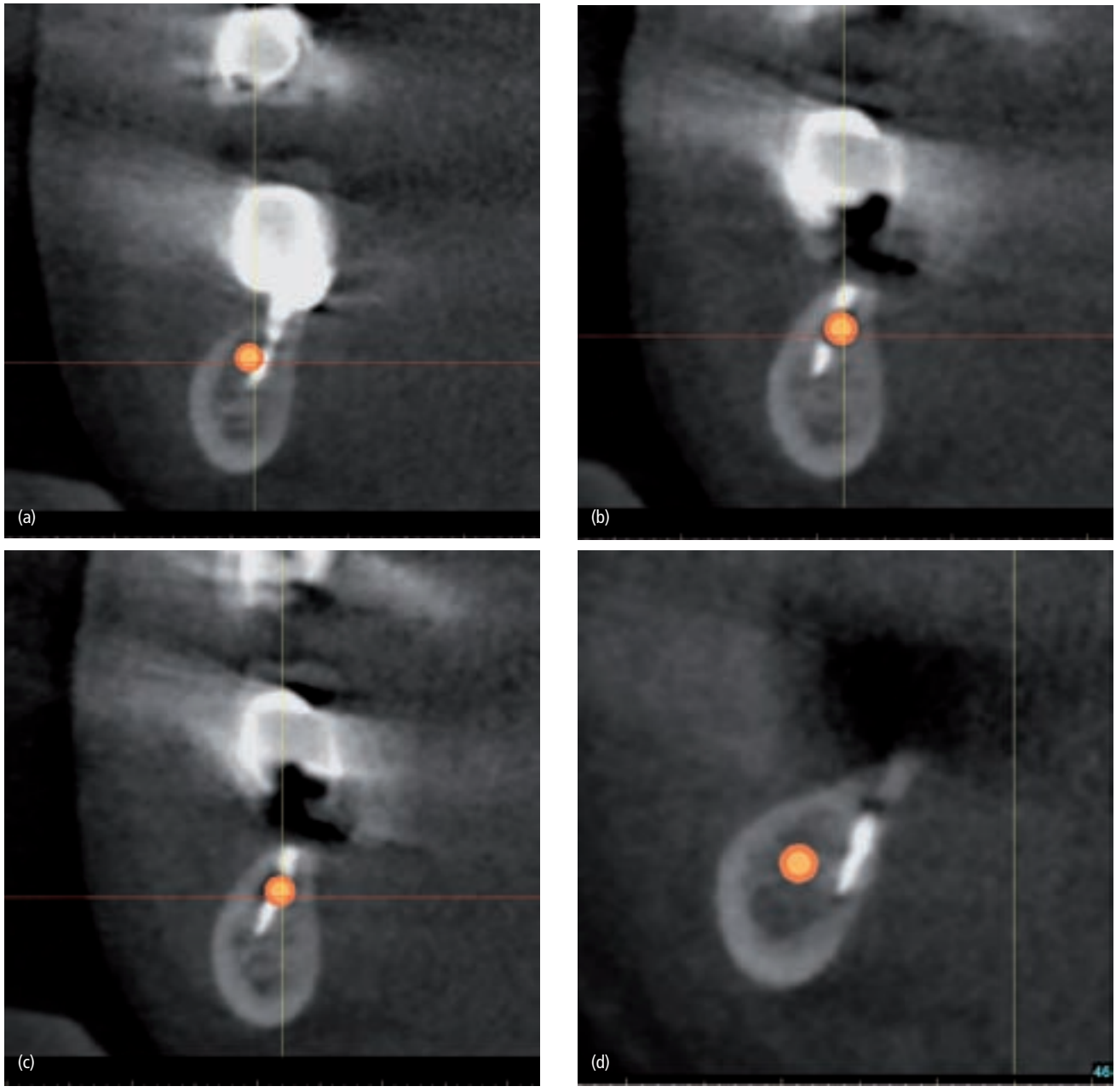


Fig. 4.8 Further investigation of the right-side blade implant revealed the clear perforation of the inferior alveolar nerve which caused long-term paresthesia (a–c). The most posterior aspect of the blade implant extension was found to be lingual to the nerve near the cortical plate (d).

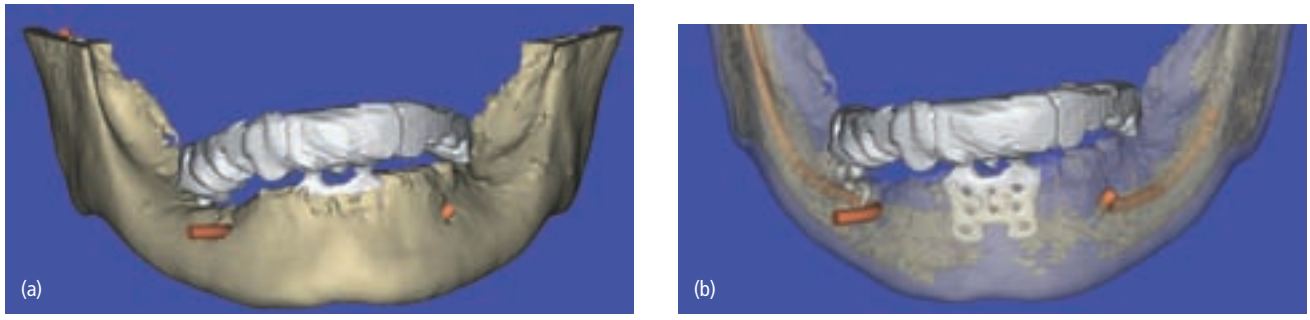


Fig. 4.9 (a) 3D reconstructed images allowing for accurate inspection of the existing fixed restoration and surrounding bone. (b) Selective transparency of various structures is an important tool for inspecting spatial relations.

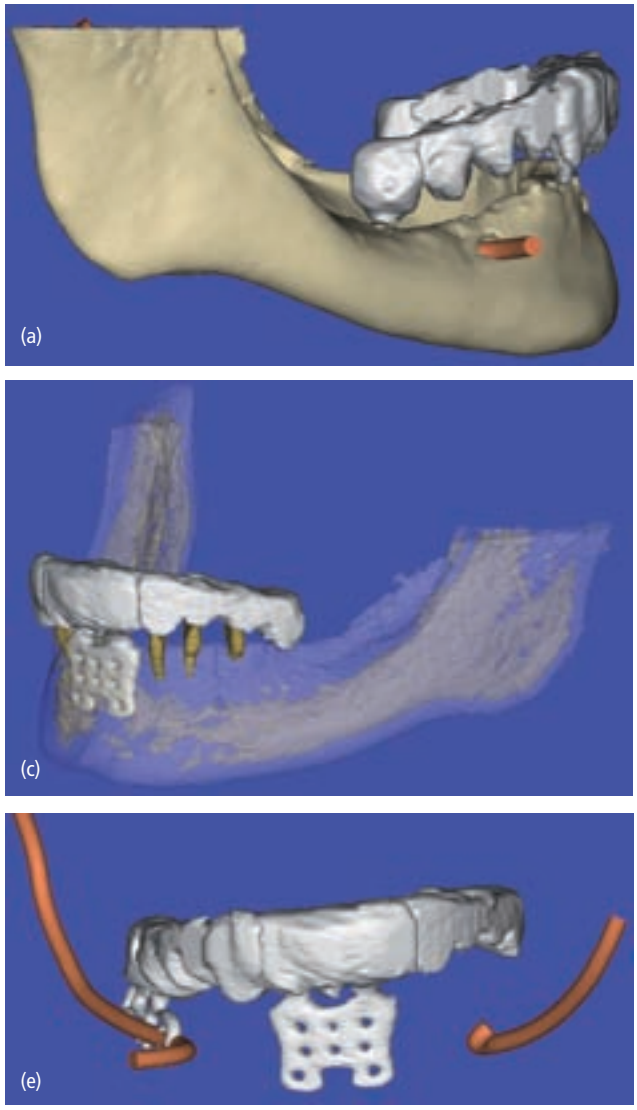


Fig. 4.10 (a) Lateral 3D view revealing the relationship between the existing fixed bridge, the bone topography, and the emergence of the mental nerve. Setting a high level of transparency enables increased visualization of (b) the posterior blade implant; (c) the existing tooth roots; (d) the anterior blade implant; and (e) the enhanced diagnostic quality when the bone is entirely removed. Note the path of the right inferior alveolar nerve.

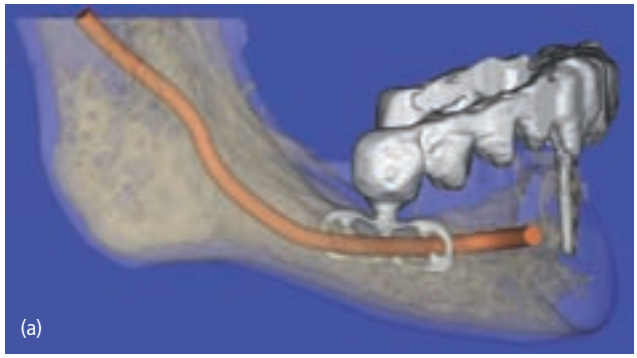


Fig. 4.11 (a, b) Advanced imaging technologies allow for complete tracing of the right inferior alveolar, revealing the path of perforation which caused paresthesia.

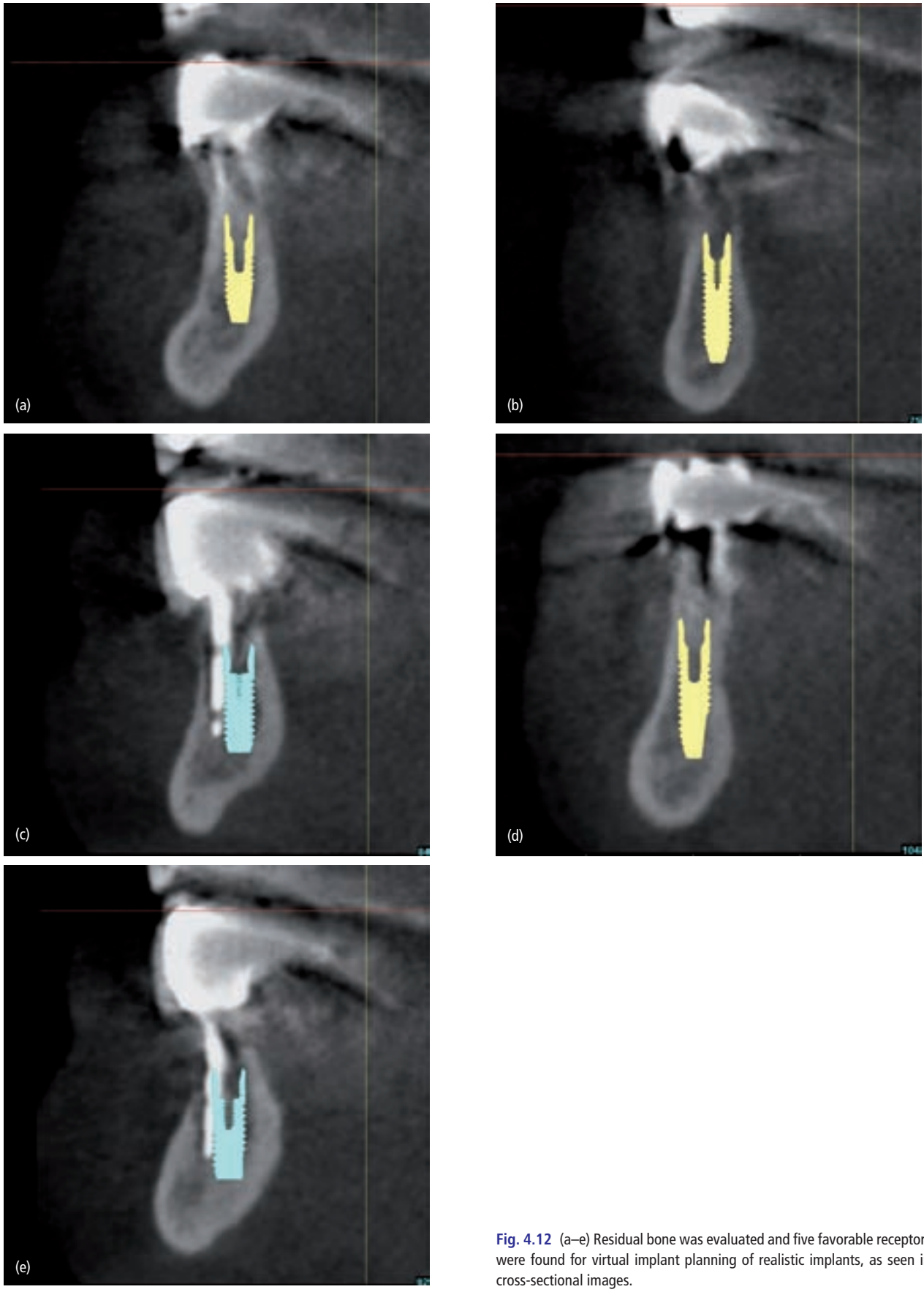


Fig. 4.12 (a–e) Residual bone was evaluated and five favorable receptor sites were found for virtual implant planning of realistic implants, as seen in the cross-sectional images.

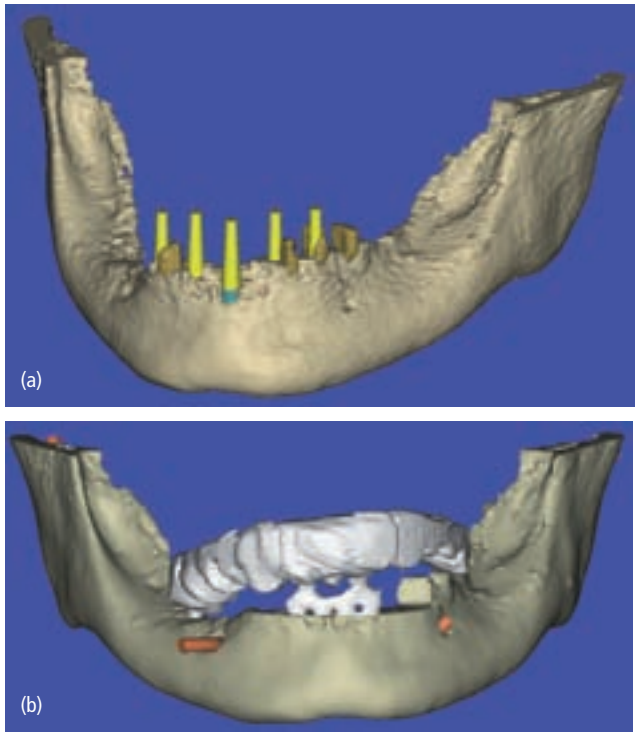


Fig. 4.13 3D reconstruction of the bone and the five anterior implants with abutment projections (in yellow) and the relationship of the existing bony topography (a) which can be virtually "leveled" to widen the ridge for implant placement (b).

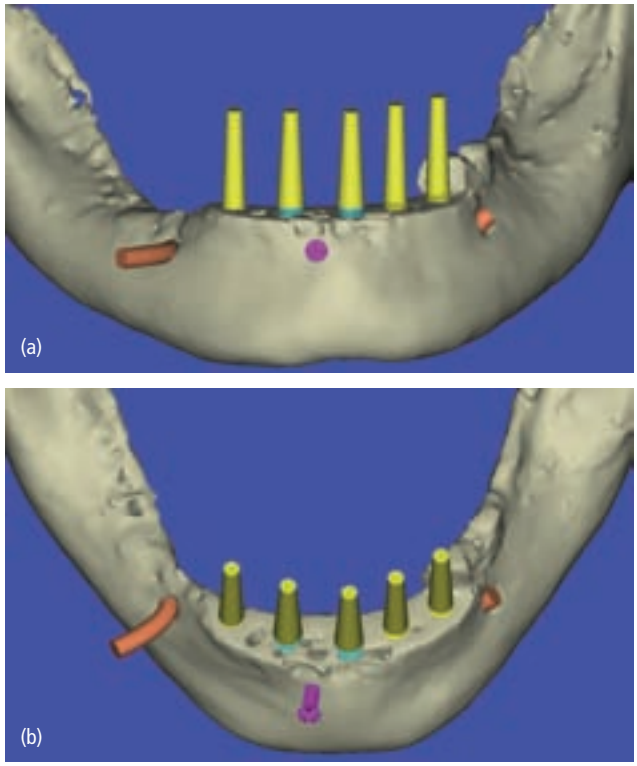


Fig. 4.14 Using advanced segmentation to remove the existing bridge affords improved inspection of (a) the parallel implants, bone width, implant-to-implant distances; and (b) the position of the fixation screw used to stabilize a bone-borne template.

predetermined. It was elected to use a bone-borne template that would benefit from external screw fixation to prevent movement (Facilitate; AstraTech Dental, Waltham, MA, USA). The fixation screw was planned so as not to interfere with the implant placement, at the midline, while allowing for adequate fixation (Fig. 4.14b).

Using a combination of selective transparencies, all of the elements of the plan were visualized (Fig. 4.15a). Removing the prosthesis reveals the parallel placement of five realistic implants (OsseoSpeed; AstraTech Dental, Waltham, MA, USA) of two different color-coded diameters (Fig. 4.15b). Using advanced "clipping" of the 3D axial reconstruction allows inspection of the implant placement, the bilateral nerves, the existing blade implants, and the position of the fixation screw (Fig. 4.16a, b). Once the final positioning has been verified, a surgical template can be virtually fabricated and evaluated (Fig. 4.16c). The CT-derived template constructed based on the virtual plan would allow for accurate drilling and subsequent placement of the five implants. The existing implants and natural teeth were removed, allowing for the tooth-borne template to be seated and fixated, facilitating osteotomy preparation and implant placement through the template (Fig. 4.17).

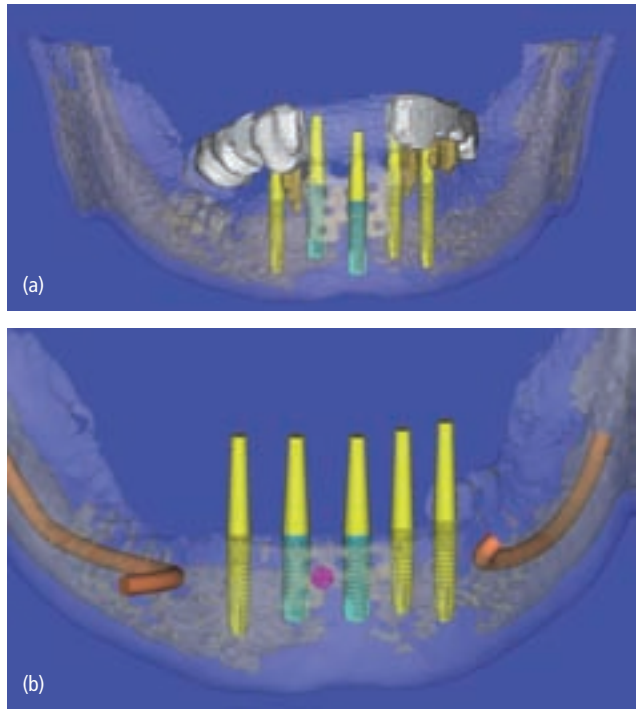


Fig. 4.15 (a, b) Selective transparency revealing the location of the anterior blade implants, two diameters of the virtual root form implants with their abutment projections (yellow).

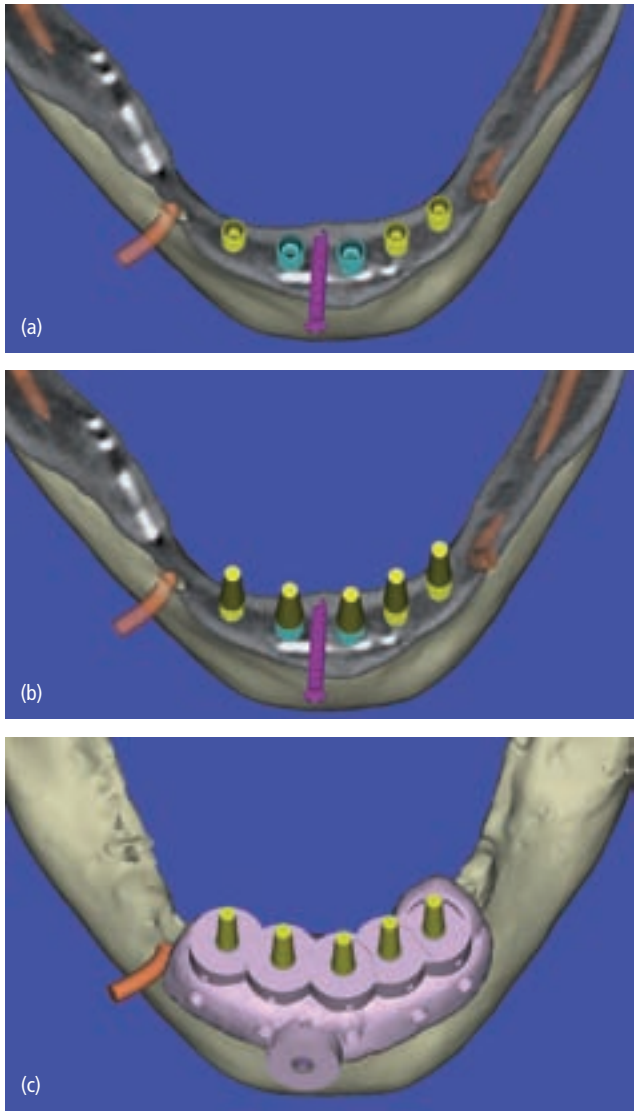


Fig. 4.16 (a, b) Using advanced "clipping" of the 3D axial reconstruction allows inspection of the implant placement, the bilateral nerves, the existing blade implants, and the fixation screw properly placed to avoid the implants. (c) A CT-derived bone-borne surgical template was then virtually designed and evaluated.

Fig. 4.17 After removal of the existing bridge, teeth, and the anterior blade implant the surgical template was seated intraorally and used to place the five anterior implants.

Case 3: Sinus augmentation complications diagnosed by three-dimensional imaging

Etiology

Problems associated with 2D imaging modalities are well documented in the literature and can include inherent distortion factors which can differ with anatomic location, foreshortening, elongation, overlapping of adjacent structures, lack of density determination, no determination of bone width or quality, and poor spatial relationship of vital structures. Despite these limitations for the past two decades the most widely used imaging technology to diagnose, plan, and document postoperative results of sinus augmentation procedures has been 2D periapical or panoramic radiographs (45). These issues alone can lead to complications of inaccurate diagnosis of implant receptor sites and areas which require bone grafting, resulting in unfavorable outcomes.

The postoperative results of a maxillary right-side sinus augmentation procedure can be viewed in the panoramic reconstruction obtained with a CT scan (Fig. 4.18). This 2D image revealed the vertical fill of the bone graft with an indication of the graft's relative density compared to the contrast of the adjacent structures. The vertical fill of the graft appeared to be sufficient for the placement of adequate length implants. The panoramic image also exhibited a thickness of the Schneiderian membrane evident in the left maxillary sinus. The patient's prior dental history was significant for a failed implant that had been placed in the posterior maxilla.

Prevention

There are four basic views that can be visualized from 3D CT/CBCT data: the panoramic, the axial (perpendicular to the panoramic), the cross-sectional (perpendicular to the axial), and the 3D reconstructed image. Each individual view modality aids in the diagnosis for that particular plane. It is the author's contention that for proper planning, all four views must be fully appreciated. The examination of the left maxillary sinus continued with the posterior cross-sectional image, which revealed a small perforation at the alveolar crest and the extent of thickening of the medial and lateral sinus walls (Fig. 4.19a). The nasal cavity and volmer can also be partially appreciated. Moving anteriorly, the cross-sectional

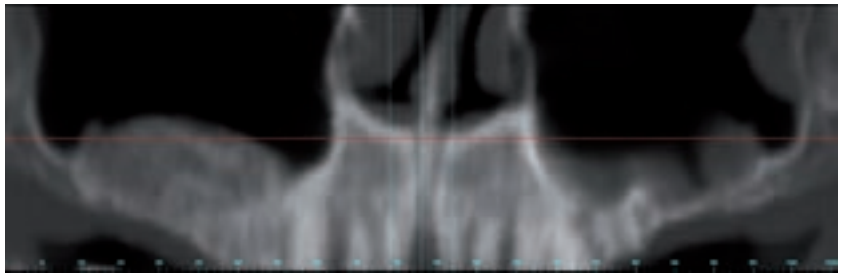
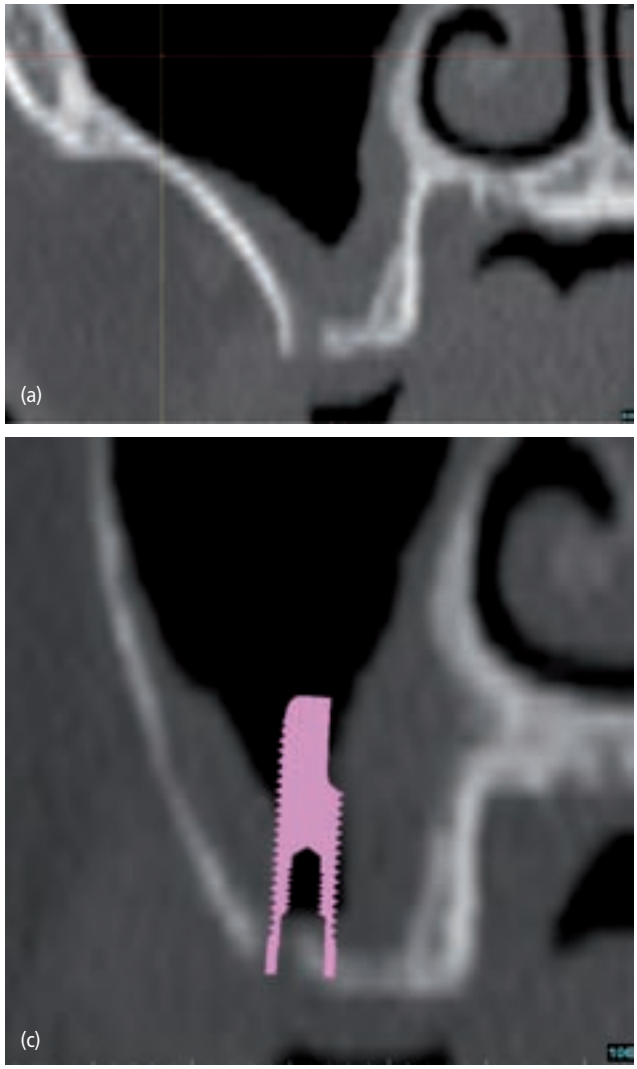


Fig. 4.18 Postoperative reconstructed panoramic image revealing a right-side augmentation procedure and left-side pathology.

slice illustrates the apparent invagination of the sinus membrane thickening which occurred from the placement of an implant in this area (Fig. 4.19b). To confirm the positioning of the failed implant, a simulated implant was virtually placed within the sinus (Fig. 4.19c). The length and diameter of the implant were estimated, and it was found to fill the "defect" which was surrounded by inflamed membranous tissue. It can be concluded that the implant was not placed into sound alveolar bone.

Treatment

Using interactive treatment planning software, the maxilla was virtually reconstructed as a 3D model. The ability to rotate the maxillary 3D reconstruction freely allows for unparalleled inspection of the sinus/nasal cavity anatomy (Fig. 4.20). Using advanced "clipping" features to slice the 3D model virtually empowers the clinician with software tools to enhance areas of interest (Fig. 4.21a, b). The lack of cortical bone continuity of the floor of the



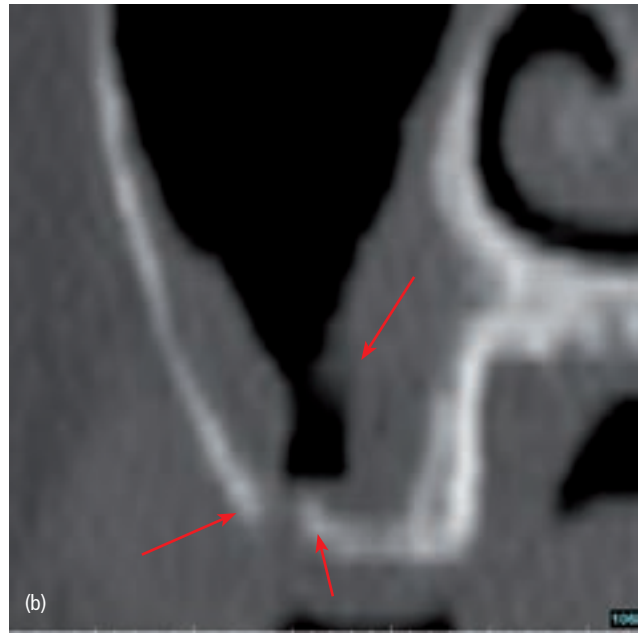


Fig. 4.19 Cross-sectional image of the right maxillary sinus revealing a thickening of the membrane (a); which had been caused by an implant which had been placed without sufficient bone support (b); as evidenced by the simulated implant placement (c).

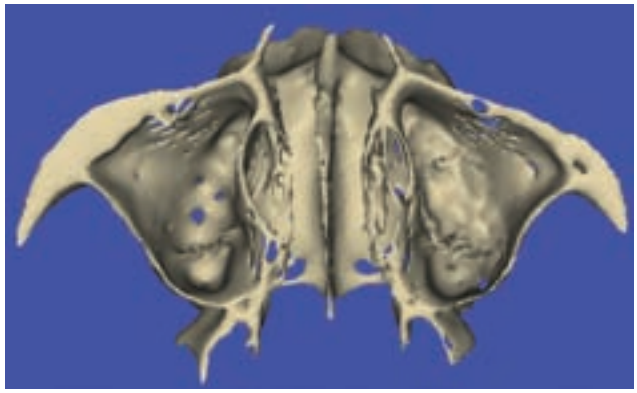


Fig. 4.20 3D reconstruction of the maxilla offering unparalleled inspection of the bony contours and volume of the bilateral maxillary sinuses.

sinus can be clearly visualized with an enhanced perception of the inner bony contours and volume of the sinus cavity. Further inspection reveals a transverse septum which divides the maxillary left sinus into separate compartments (Fig. 4.21c). A new treatment plan was then developed to fill the left sinus with a new bone graft, and repair the defect in the sinus floor with the anticipation of placing three implants to support a fixed restoration in this posterior segment.

Once the graft had matured, three implants were planned for the right and left sinus augmentation receptor sites, six implants in total. A postoperative CT scan was completed to confirm the placement of the implants. The panoramic reconstruction derived from the CT scan data illustrated the positioning of the six implants within the bilateral grafted sites (Fig. 4.22a). Using the panoramic view, the implant positioning can be assessed within the limitations of this 2D slice. It is apparent that the right-side graft healed with less volume of bone than the left-side graft, which resulted in shorter implants on the right side than on the left side. The question of how much volume should surround each implant may be a matter of clinical philosophy as this can only be assessed through postoperative CT/CBCT scans, a protocol that has not been routinely advocated. The axial image can be useful in determining how the implants were placed in relation to the facial–palatal aspect of the maxillary alveolar ridge (Fig. 4.22b). Implant-to-implant distances can also be fully appreciated in this important view. It can be noted that the implants on the right side appear to be more centrally placed, while the implants on the left side appear to be placed more toward the facial aspect of the alveolar ridge crest. The graft density surrounding the implants and the apparent radiolucent areas in between implants can be appreciated. This radiolucency is often misdiagnosed as bone loss or lack of bone. The black appearance between adjacent implants is a phenomenon known as "beam hardening", which is a commonly encountered artifact in CT scan imaging. In technical

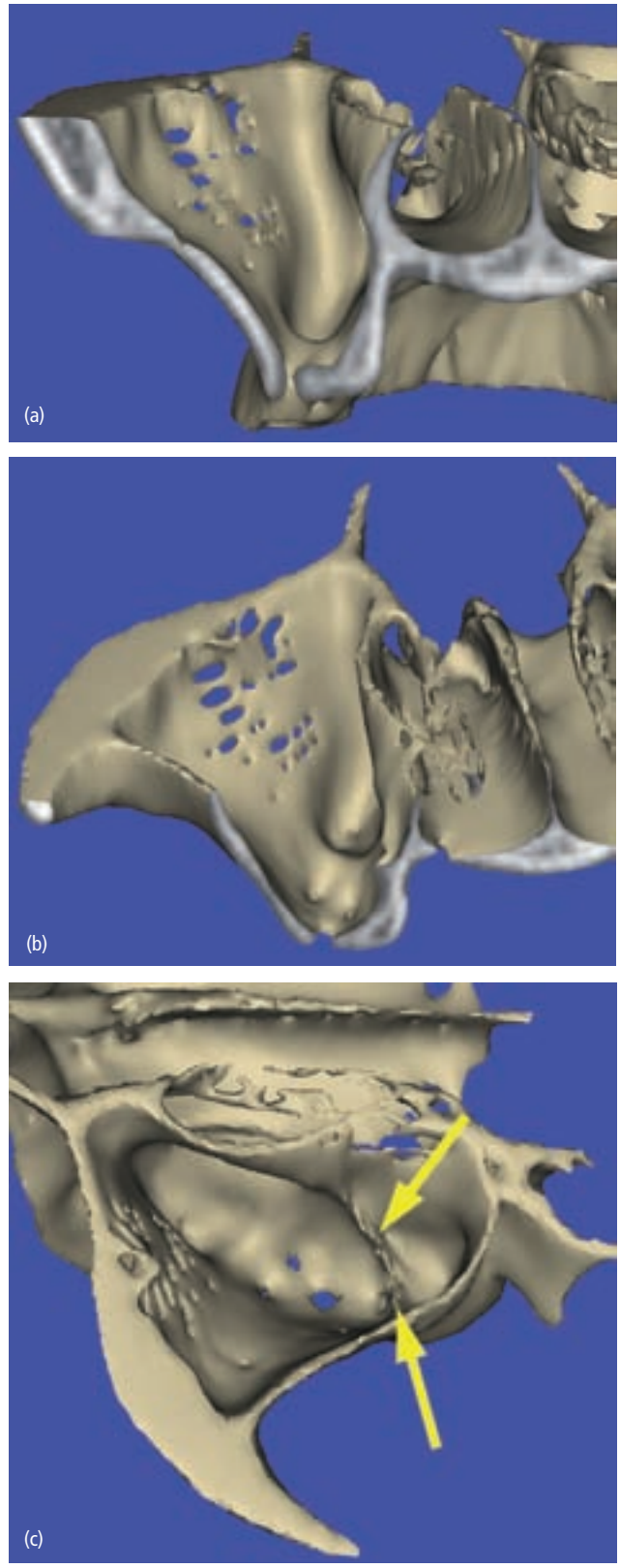
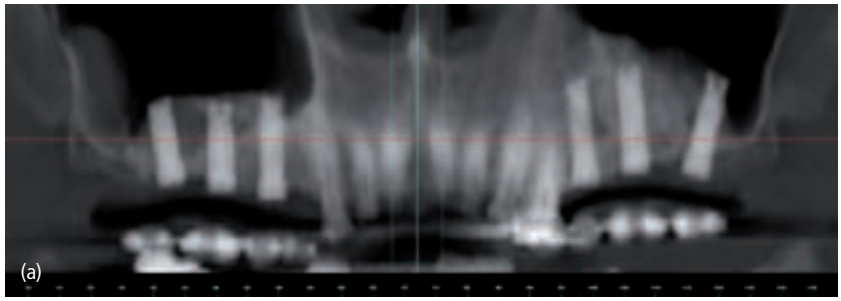


Fig. 4.21 Slicing through the 3D image in cross-section reveals where the implant perforated the floor of the sinus (a, b) and the transverse bony septum (c).



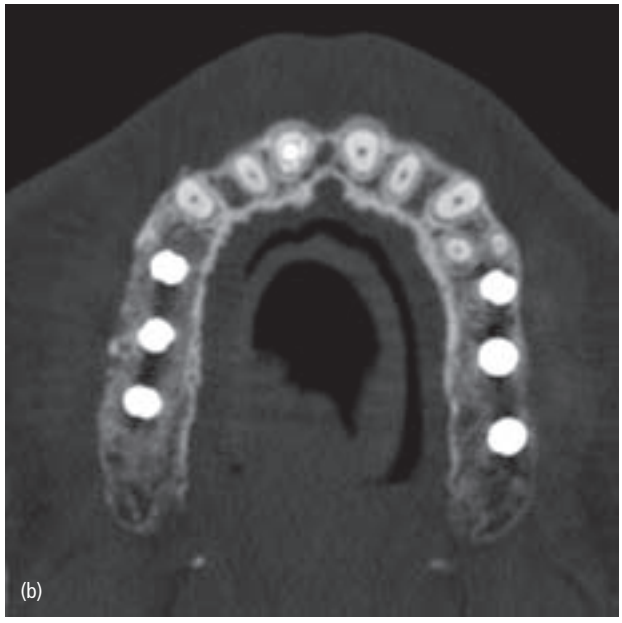
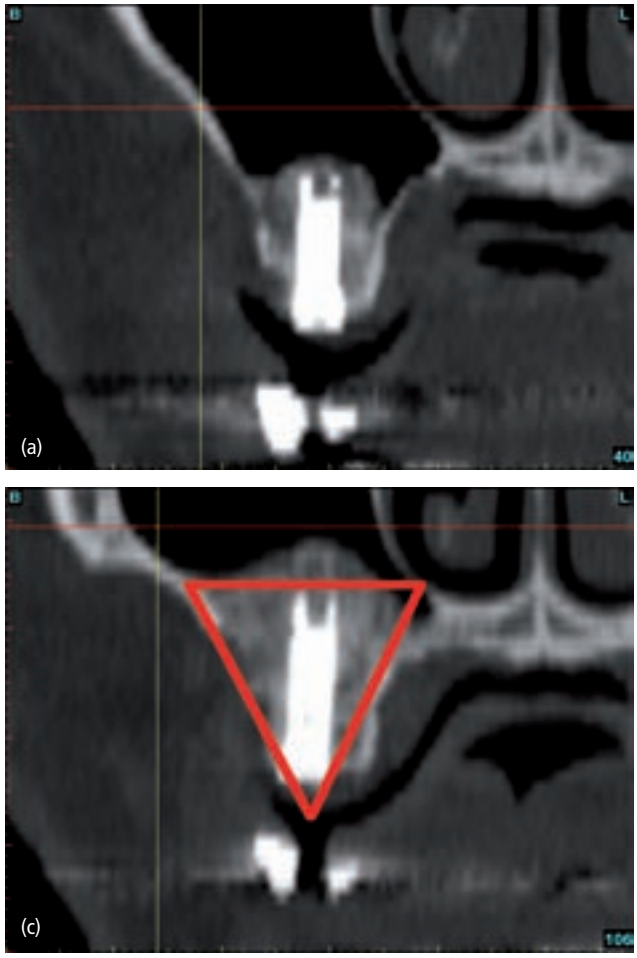


Fig. 4.22 Postoperative panoramic radiograph showing a discrepancy between the three implants placed in the right sinus augmentation and the three implants placed in the left sinus graft (a); the axial view shows the distribution of the implants and the radiolucent artifacts known as beam-hardening (b).

terms, beam hardening is "the process of increasing the average energy level of an X-ray beam by filtering out the low-energy photons" (46). In simple terms, the proximity of the two very opaque metal objects of very high density tends to change the value of the surrounding structures, basically inverting the gray-scale "pixels" from white to black, thus giving the appearance of radiolucency.

Postoperative CT/CBCT images are very important in confirming that implants have been properly positioned in relationship to the newly grafted host bone and the desired prosthetic restoration. A radiopaque scanning appliance worn during the acquisition of the CT scan image helps to provide the link between the underlying bone and the envelope of the tooth to be replaced. The barium sulfate material can be used in differing concentrations (10%–20%) and to highlight either the teeth or the entire prosthesis including the flange area. The scanographic template used for this patient contained 20% barium sulfate to create fully contoured teeth embedded in a clear acrylic base. In addition, to gain direction and angulation, holes were drilled through the occlusal surface. The scanographic template was used as a surgical drilling guide to prepare the osteotomies into the grafted sinus on the maxillary right side. The radiopaque tooth can be seen hovering over the site of an implant placed in the right-side grafted sinus (Fig. 4.23a). The implant was positioned within the bulk of the bone volume, although the apical portion is minimally covered. The 3D reconstruction can be sliced to reveal the inner aspect of the sinus (Fig. 4.23b), which offers a different perspective than the 2D cross-sectional slice. Note that again the implant was well positioned within the volume of the graft and the zone of the "triangle of bone®" (TOB), as originally described in 1992 and first published in 1995 (47–50) (Fig. 4.23c). Therefore, when technology is properly utilized, implant placement can be more accurate and consistent.

For some unknown reason, the surgical guide was not used to prepare the osteotomies for the maxillary left side. The left-side graft placement contained considerably more bone volume and height. However, the most anterior osteotomy was prepared "free-hand" and the implant was placed into the site using a minimally invasive "flapless" surgical approach. Unfortunately, this angulation did not result in the proper placement of the implant. The scanographic template had a guide hole indicating direction for the implant. However, in the postplacement CT scan, the implant can be seen perforating the facial cortical plate (Fig. 4.24a). The apical



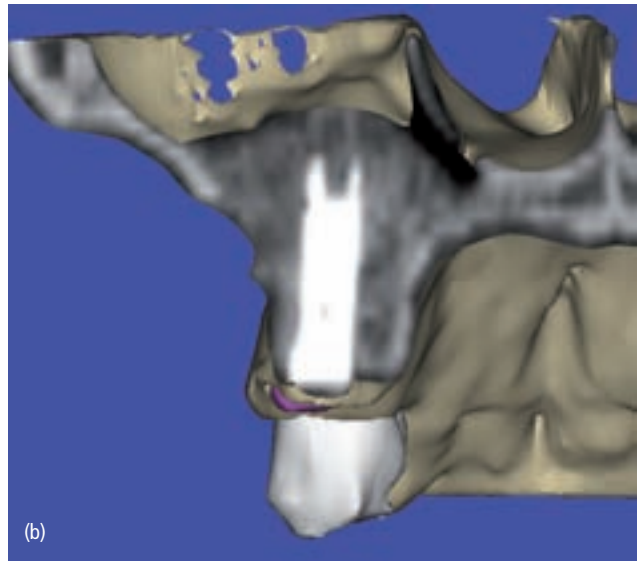
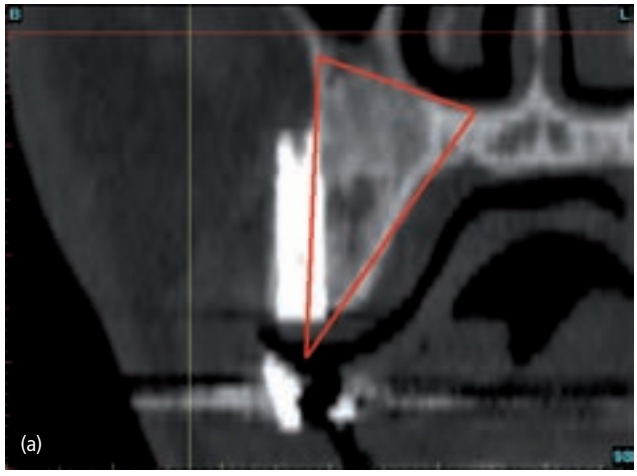


Fig. 4.23 Postoperative cross-sectional view of the right-side implant placement with (a) the radiopaque scanning appliance; (b) the 3D cross-section; and (c) a cross-section of the left-side implant placed within the "triangle of bone".

position of the implant has been placed into the vestibule, missing the zone of the TOB entirely (Fig. 4.24b). The most distal implant also missed the volume of the bone graft by piercing through the graft as visualized in the panoramic view (Fig. 4.22a). However, the direction of the implant and the lack of bone between the palatal aspect of the implant and the medial wall of the sinus would be impossible to detect without 3D imaging (Fig. 4.25a). Using the 3D clipping functionality allows further inspection of the portion of the implant exposed within the sinus (Fig. 4.25b). The 3D reconstruction of the maxillary left side displays the facial perforation of the anterior implant (Fig. 4.26). The view from above reveals the extent of fill for both the left- and right-side sinus cavities while exposing the perforations of two out of the three implants placed on this side (Fig. 4.27a). Using advanced segmentation and masking tools, different anatomic structures can be separated from the 3D image, allowing for additional diagnostic insight (Fig. 4.27b). Color can be used to isolate each of the implants and differentiate the sinus graft from the maxilla to increase diagnostic accuracy (Fig. 4.27c).

The segmentation process clearly reveals the anterior implant (magenta colored) perforating the facial plate of bone (Fig. 4.28a). Selective transparency was previously described as the ability to control the opacity for different anatomic 3D volumes which creates a layered effect when using the interactive software application. The use of selective transparency and segmentation of the various entities exposes the position of the implants in proximity to the anterior adjacent teeth. Therefore, by adjusting the levels of transparency the maxilla was made more translucent than the adjacent opaque tooth roots, bone graft, and the three implants, affording unique insight (Fig. 4.28b). This virtual investigation reveals that the anterior implant was positioned through the facial cortical bone, and confirms angulation in close proximity to the adjacent root of the natural bicuspid tooth. The most posterior implant can also be seen as perforating through the sinus grafted bone, leaving threads exposed within the sinus cavity. Slicing laterally through the 3D reconstruction allows further inspection of implant-to-tooth position, implant-to-implant position, and spatial relation of the implants to the graft volume. The distal angulation of the posterior implant can be clearly visualized perforating into the sinus, substantially missing the target area of bone volume (see arrows) (Fig. 4.28c).



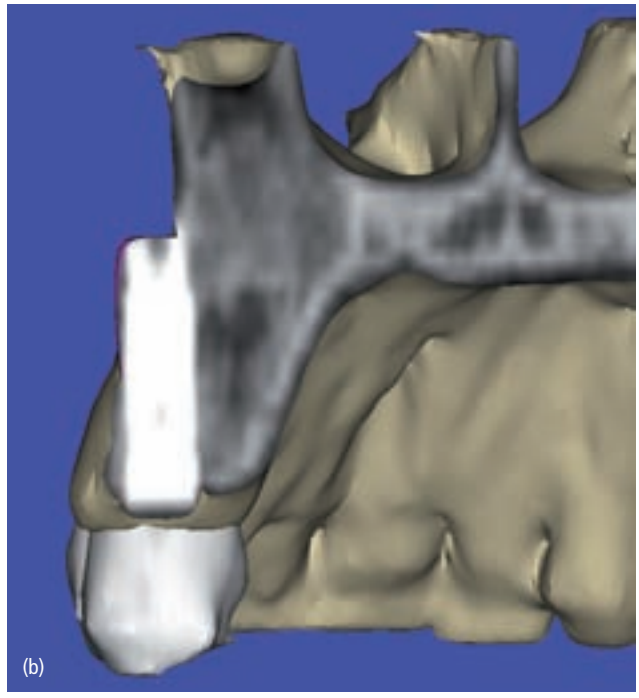
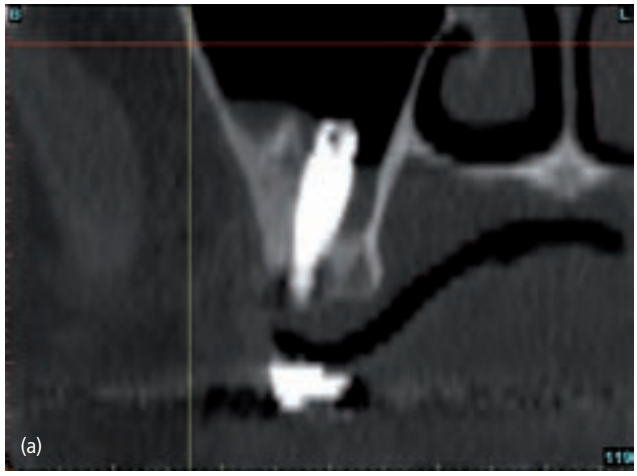


Fig. 4.24 The most anterior implant on the left side was placed "free-hand", which resulted in perforation of the labial cortical plate, missing the augmented bone (a); (b) the 3D cross-section helps to reveal the apical perforation.



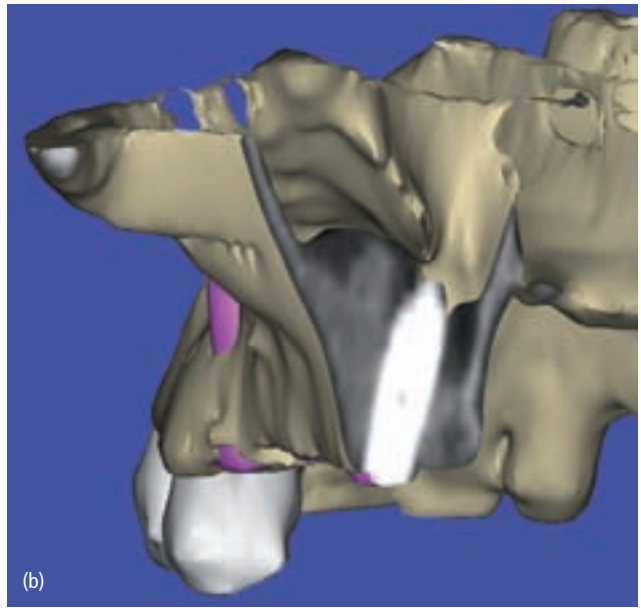


Fig. 4.25 The most posterior implant also missed the augmented site, which could only be detected within a 3D cross-sectional view (a); (b) the bone did not fully extend to the medial wall of the sinus.

Summary of case 3

When the original augmentation procedure was completed for the right maxillary sinus, a postoperative CT scan was taken. The extent of the fill was noted, and it was determined that although it was adequate, the vertical height could have been improved to facilitate the placement of longer implants. Using preoperative CT/CBCT helps clinicians to understand the sinus topography and volume of bone required to fill the cavity to a successful level for long-term integration of the implants.

It appears from the presentation that the left maxillary implant failed because there was insufficient bone support, which may have been undiagnosed at the time. Chappuis stated that, "As implant dentistry is becoming more and more popular among practitioners, and ever more demanding procedures for initial site development in jaws with bony deficiencies are being introduced into daily practice, the displacement of dental implants into the maxillary sinus during implant placement may become a more frequent complication" (51). CT imaging technology offers highly accurate insight for under-

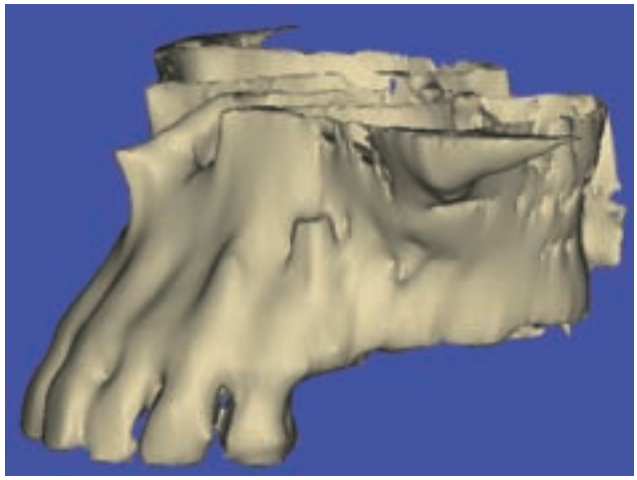


Fig. 4.26 Lateral 3D constructed view showing how the anterior implant was angulated toward the adjacent tooth root, while perforating the facial cortical bone.

standing why implants or bone grafts fail. The perforation of the alveolar crest was still present, and would not regenerate without surgical intervention (see Fig. 4.19a). When the left maxillary augmentation was completed, and with an appreciation of what had transpired on the right side, enough bone graft material was used to fill the cavity to support longer implants (Fig. 4.22a). The difference in implant lengths can be directly compared for each of the two sides. When it was time to place the implants a surgical guide was used for the right side and not the left side. The volume of bone on the left side was adequate on the facial and the palatal aspects of the implants, but barely covered the apical portion of the implants (Fig. 4.23a). However, this should not be a problem in the long term. The middle implant placed in the maxillary left sinus reveals a good thickness of bone apical to the implant, with good adaptation of the graft to the medial wall of the sinus (Fig. 4.23b, c).

The issue for this case involves two implants placed in the maxillary left sinus. In viewing the panoramic reconstruction in Fig. 4.22(a), the difference in angulation and positioning from the implants on the left versus the right side is readily apparent. However, it is the cross-sectional slices and the 3D reconstruction that are the most revealing. The anterior-most implant missed the bone graft entirely. This is clearly not acceptable, and could have been avoided by using a properly constructed surgical guide and/or by raising a flap to visualize the site. While there is a place in implant reconstruction for flapless surgery, in the author's opinion, this modality should only be attempted when (i) there is a CT/CBCT scan to confirm that there is adequate bone present for integration, (ii) there is an abundance of keratinized tissue, and (iii) a surgical template is used to place the implants within the volume of bone.

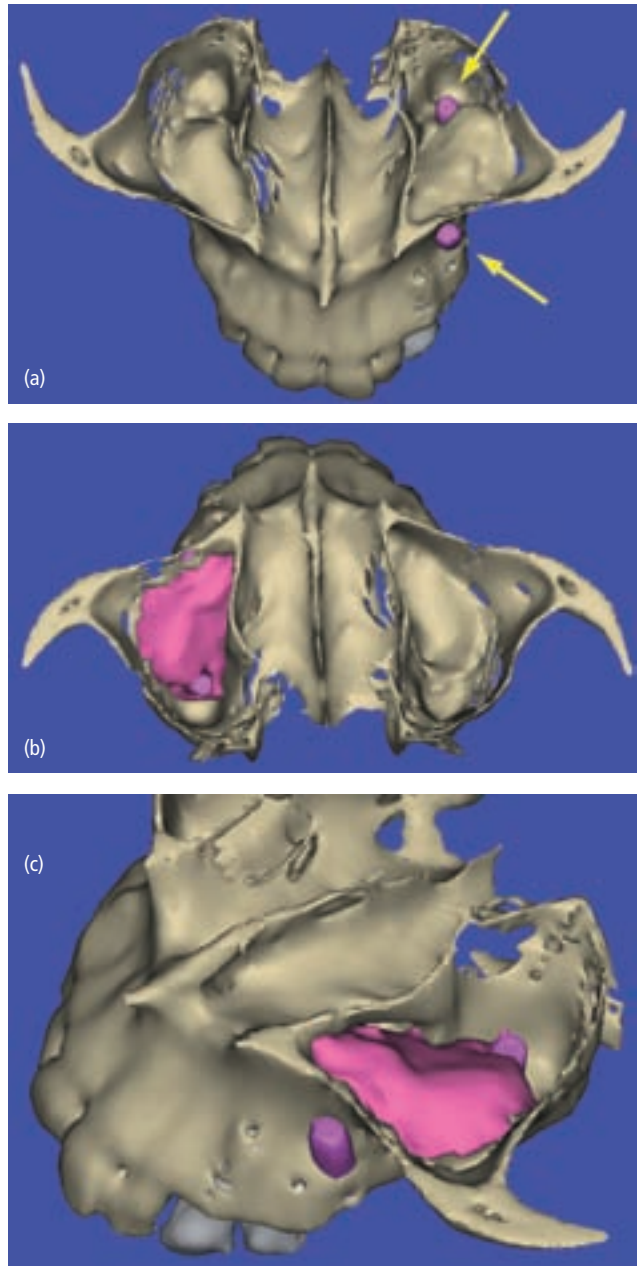


Fig. 4.27 Rotation of the 3D volume revealing the extent of bone fill within the sinus, and clearly demonstrating (a) how the two implants missed the target (arrows); and (b) the difference in fill between the right and left side; (c) however, it is the use of segmentation and color that allows for improved visualization.

Another common contributing factor to malpositioning of implants relates to the construction of the scanographic template. When the template has holes predrilled, they are usually placed within the central fossa of the tooth. The angulation can be arbitrary. When the scan is then taken, and the predrilled hole visualized, often there is an attempt to move the implant so that the abutment will emerge through the hole. If the angulation and positioning of the hole are correct, this can work

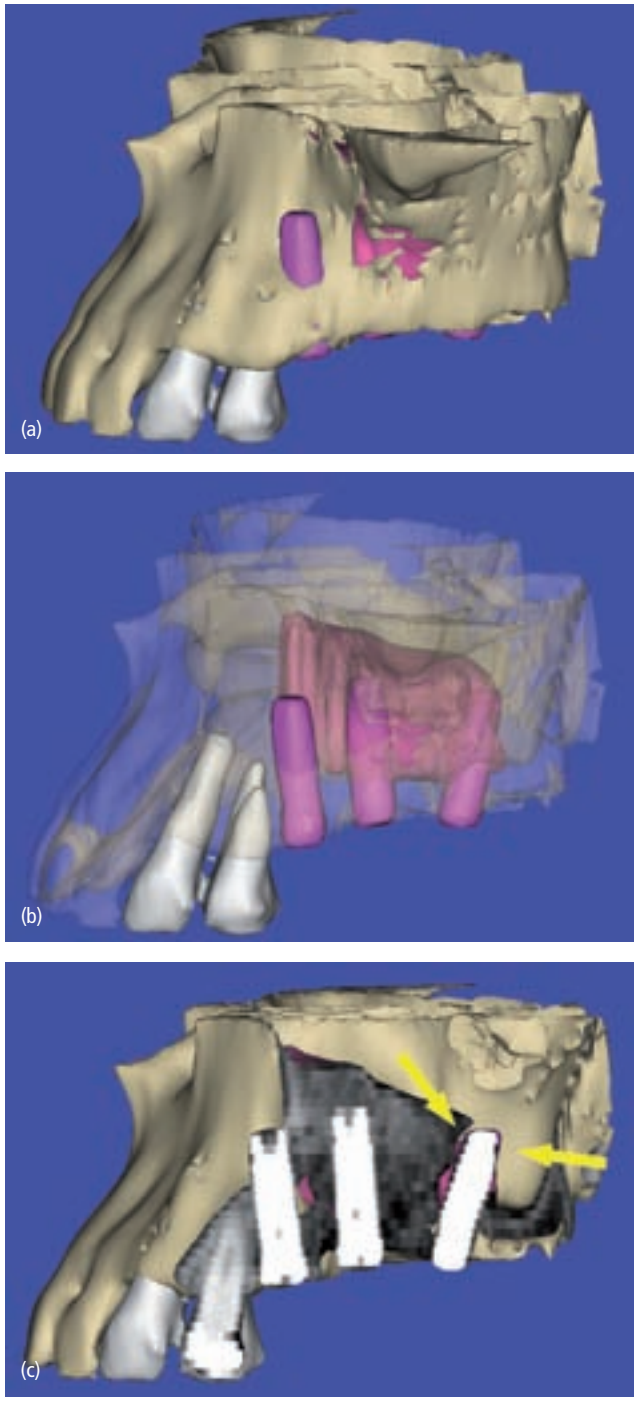


Fig. 4.28 (a) Advanced diagnostic tools are helpful in separating the various anatomic structures, including (b) the proximity of the adjacent tooth roots; (c) further enhanced by slicing through the lateral aspect of the maxilla showing the distal angulation of the posterior implant (arrows).

out well. If the angulation and positioning of the hole are not ideal, it can lead to placing the implant in the wrong position. The hole drilled through the template in Fig. 4.24(a), if followed, would create an osteotomy and subsequent placement of the implant which would perforate the facial plate, missing the bulk of available bone. Therefore, the proper protocol is to create a full-contour barium sulfate tooth, without predrilled holes, for implant planning. The implant can then be positioned within the TOB, and a simulated abutment projection used as an aid to achieve restoratively driven implant reconstruction. A CT-scan software application derived template can then be used for surgical guidance to ensure positioning within the most volume of available bone. Using this concept a simulated realistic implant 4.5 mm wide by 19 mm long (OsseoSpeed AstraTech Dental) could have been placed to take advantage of the entire bone volume (Fig. 4.29a). A realistic 15° angulated abutment was then placed on the implant to fall within the envelope of the desired tooth position (Fig. 4.29b).

Case 4: Complications in the mandibular symphysis related to diagnostic imagery

Failed implants

The anterior mandible has often been thought of as one of the safest areas to place implants owing to the assumption that there will always be dense bone anatomy and limited exposure to vital structures. The posterior mandible has a defined lingual concavity, which can be palpated. The anterior mandible can have a conventional shape which is favorable to implant placement, or can be shaped like an hour glass, which would not be conducive to implant placement. Certainly the course of the mandibular canal and potential anterior loops of the mental nerve should be considered for this region, but cannot be consistently or accurately detected with 2D radiography. Implant complications can result from poor planning, poor execution, and a poor understanding of the existing patient anatomy. Therefore, problems can occur when the natural anatomic variations are not fully appreciated. In addition, without 3D imaging and associated tools, the etiology of why complications have occurred may not be recognized.

A female patient presented with what was termed "cluster failures" in the anterior mandible. The referring doctor claimed that the implants were "tainted" in some manner, and thus all failed owing to microscopic surface contamination or machining of the implants. A CT scan was completed for this patient to help determine the cause of the failures, and to determine the next course of treatment. The reconstructed panoramic view reveals two remaining implants of the original seven that were placed in the anterior mandible (Fig. 4.30). The symphysis exhibits several large radiolucent areas where the implants once resided. The extent of the damage can better be appreciated in the axial view (Fig. 4.31a). The inferior border of the mandible anteriorly was intact and demonstrated dense cortical bone anteriorly. Moving

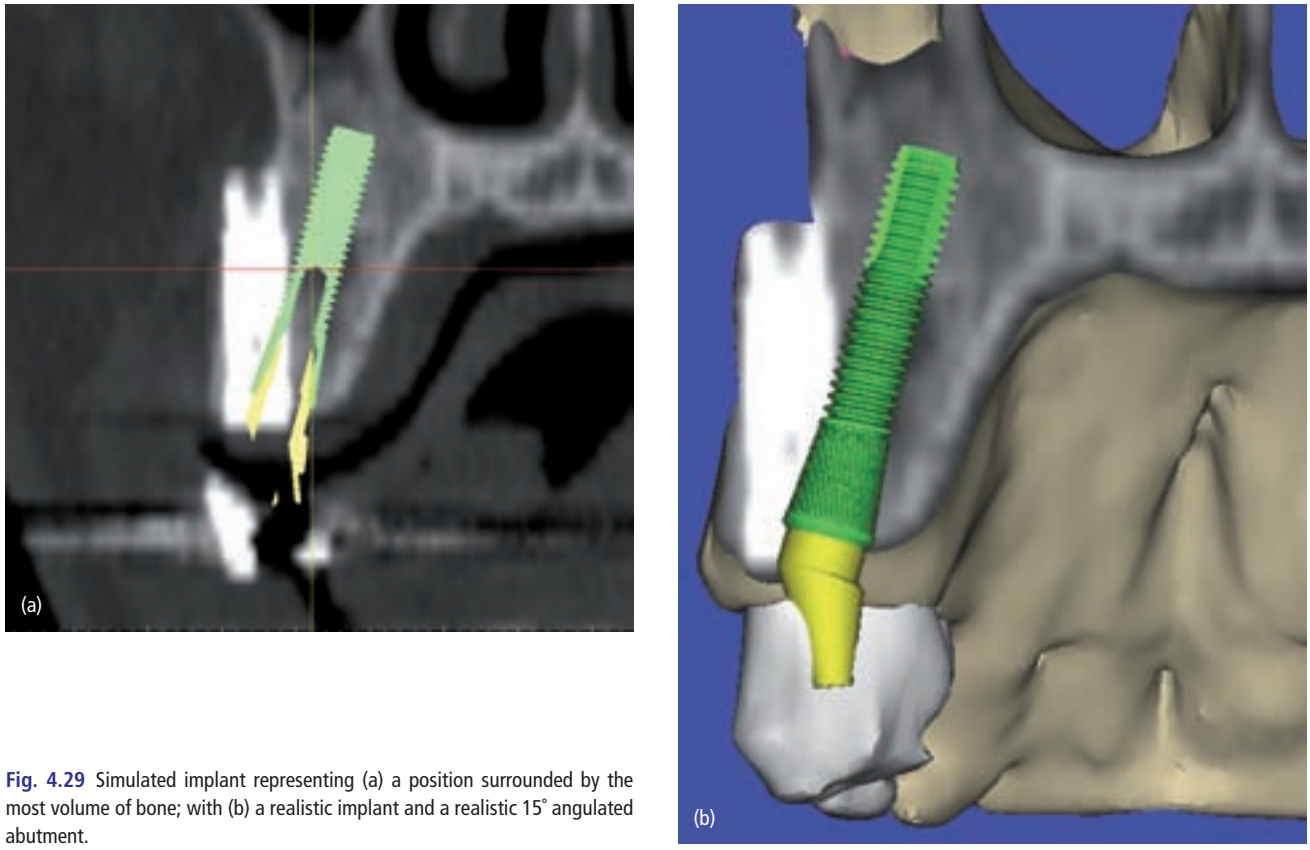


Fig. 4.29 Simulated implant representing (a) a position surrounded by the most volume of bone; with (b) a realistic implant and a realistic 15° angulated abutment.

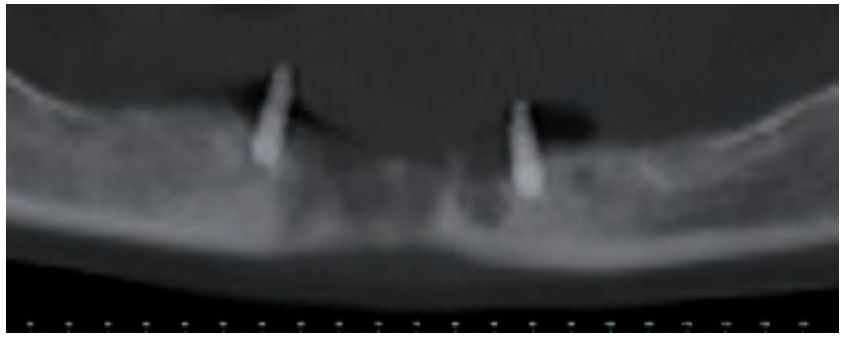
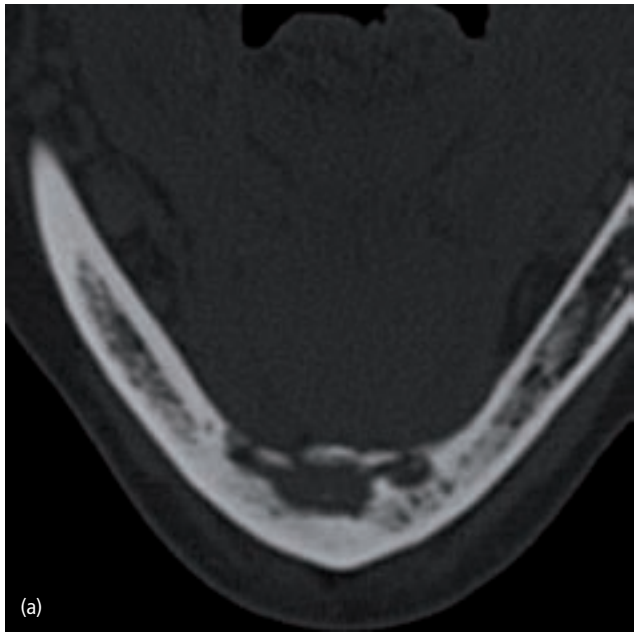


Fig. 4.30 Reconstructed panoramic image revealing two remaining implants of the original six placed in the anterior mandibular symphysis.

superiorly, the facial and lingual cortical plates were thin and perforated (see arrows) (Fig. 4.31b). The mental foramina can be seen in this view bilaterally, along with one of the remaining implants. Further investigation of the cross-sectional views revealed a through-and-through perforation of the anterior mandible from facial to lingual, above the dense basal cortical bone of the inferior border (Fig. 4.32a, b).

Etiology

The cross-sectional views capturing the position of the right and left remaining implants disclosed perhaps the final clue to discovering the true cause of the failures. The right implant can be seen in Fig. 4.33(a) and the left implant in Fig. 4.33(b). Three-dimensional reconstructions were also completed, and offer additional information regarding the residual mandibular anatomy (Fig. 4.34a, b). The bone destruction was obvious. Even though it is highly unusual for four implants to fail at once, the causative factor was most likely not due to the manufacturing tolerances of the implants. Using the remaining implants as a guide, the cross-sectional images reveal angulations which are inconsistent with implant survival. A simulated implant was placed parallel in the lingual vestibule at the same angle as one of the original implants (Fig. 4.35a). To confirm the angulation, length, and diameter, it was moved directly over the remaining implant (Fig. 4.35b). The simulated implant was next moved to a cross-sectional image where one of the



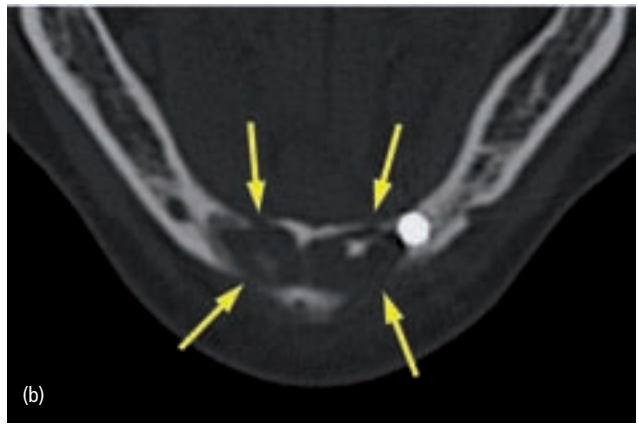
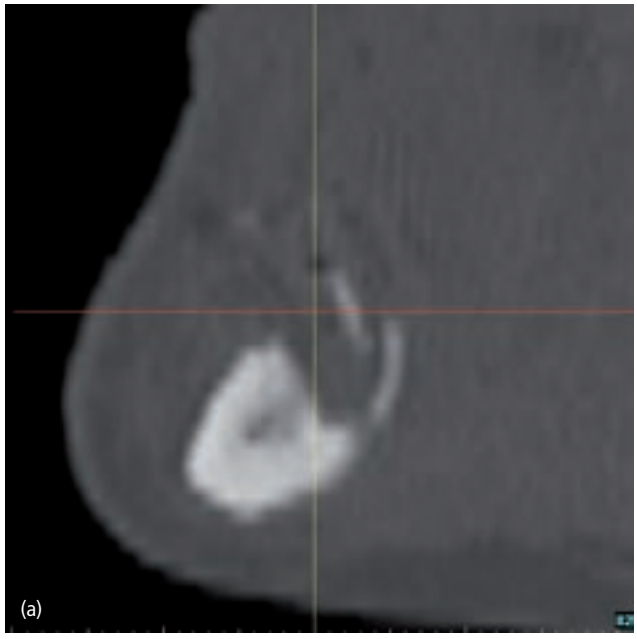


Fig. 4.31 (a) Axial view revealing the radiolucent areas where the implants failed; (b) full extent of bone destruction amplified through the various slices (see arrows).



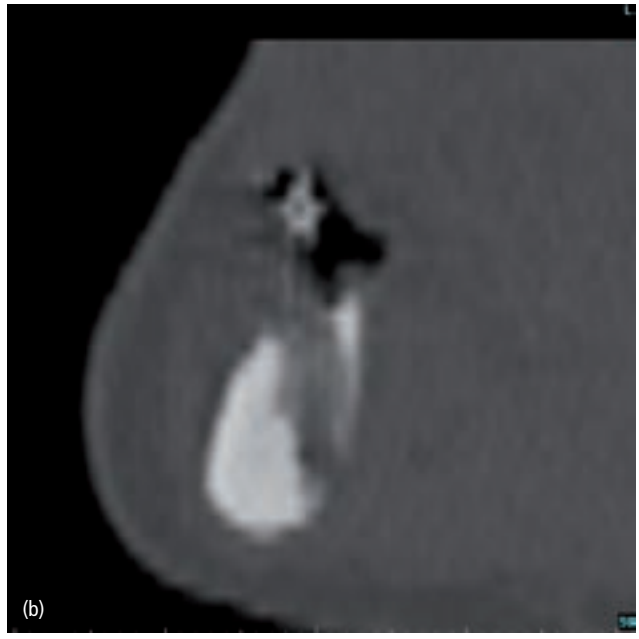


Fig. 4.32 (a, b) To investigate the remaining bone further, cross-sectional images revealed a through-and-through perforation above the dense basal cortical bone.

implants had failed, leaving a large radiolucent defect (Fig. 4.35c). This exercise continued with the axial image allowing for inspection of each of the four radiolucent areas where implants once resided (Fig. 4.36).

Prevention

The 3D reconstruction revealed the anterior mandible with the two remaining implants using the interactive software tools to segment the entities (Fig. 4.37a). A realistic external hex-type implant (yellow) was superimposed over the left implant to mimic its position (Fig. 4.37b). The original implant was then replaced with the new simulated implant to understand better what had caused the implants to fail (Fig. 4.37c).

Treatment

Four additional virtual simulated implants were then created and placed into the anterior mandible at the same angle and position as the original implants as seen in the occlusal view of the 3D reconstruction (Fig. 4.38a).

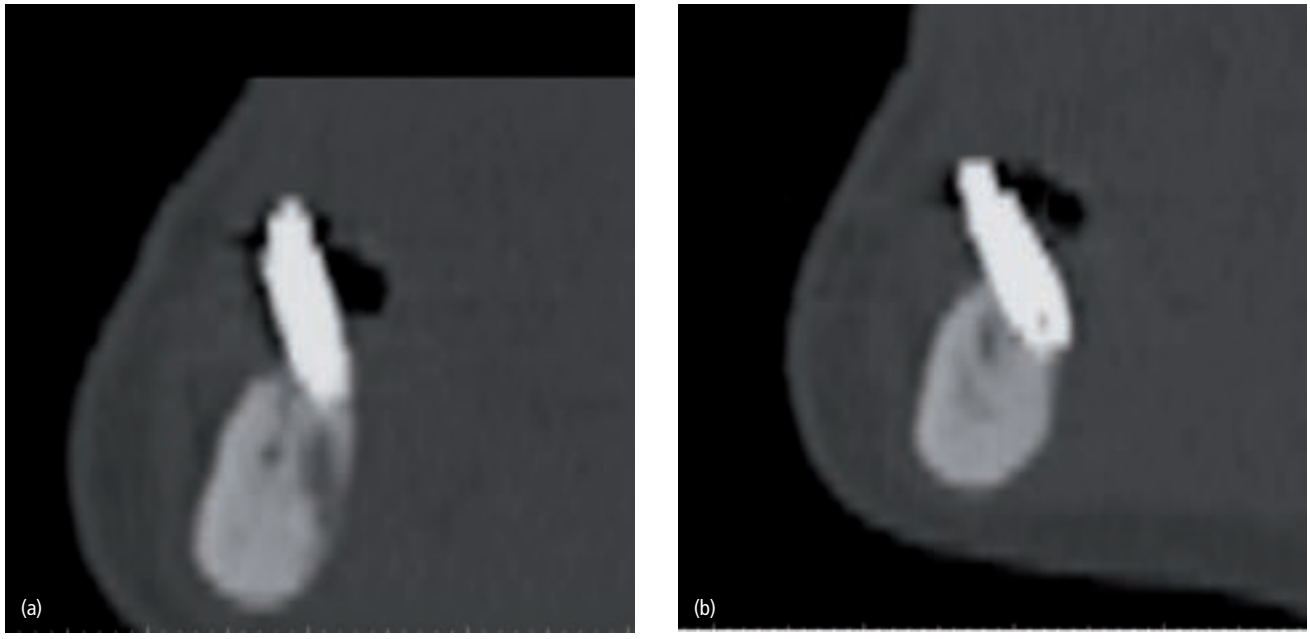


Fig. 4.33 (a, b) Cross-sectional images of the two remaining implants were an important clue to why the implants might have failed.

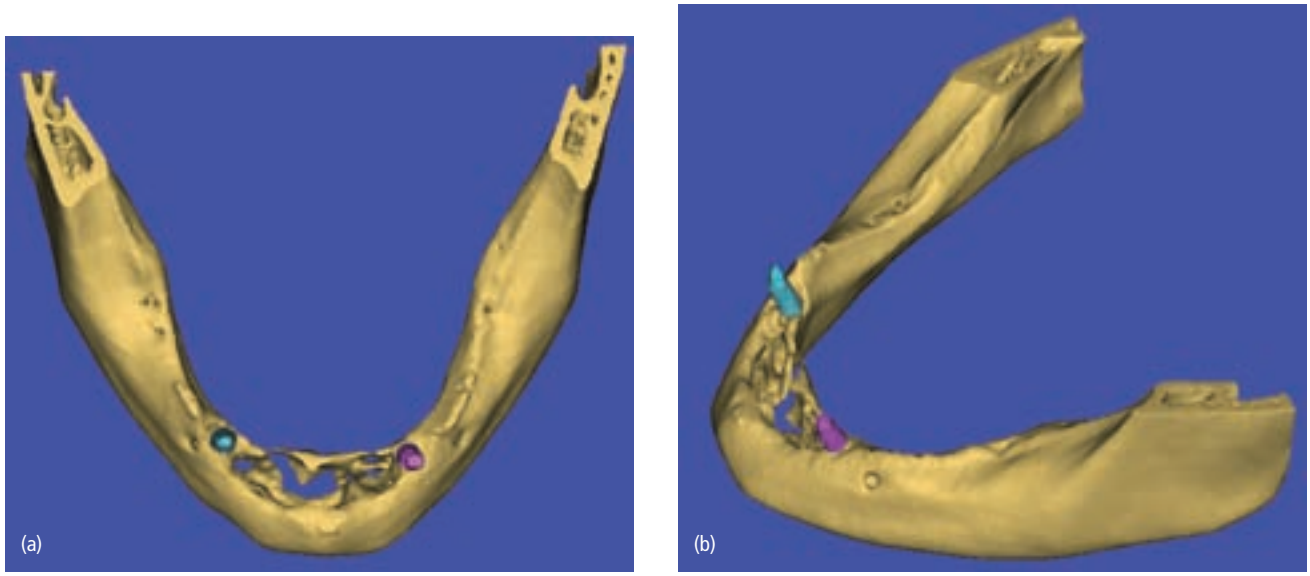


Fig. 4.34 3D reconstruction illustrating the entire scope of the mandible and obvious bone destruction (a, b).

Again, the bone destruction is readily apparent. The lingual view offers an estimation of the original height of the anterior mandible (compared to the right and left remaining implants), while revealing the perforations of the lingual cortical plate (Fig. 4.38b). To illustrate the point further, the 3D reconstruction was sliced to show the severe angulation of one of the remaining implants (Fig. 4.39a). The superimposed realistic virtual implant offered additional information about the malpositioned implant (Fig. 4.39b). Moving toward the midline, the extent of the symphyseal defect was noted (Fig. 4.39c). To complete the process, all of the simulated "original" implants were positioned to reflect their angulation when initially placed, resulting in perforation of the lingual cortical plate, eventual failure, and removal. The line-up of the failed implant simulations is seen at the same angulation as the remaining right-side implant which led to lingual perforations (Fig. 4.39d).

Summary of case 4

Two-dimensional panoramic radiographs have inherent limitations and cannot reveal the bone density, bone width, or trajectory of the bone. Therefore, if these

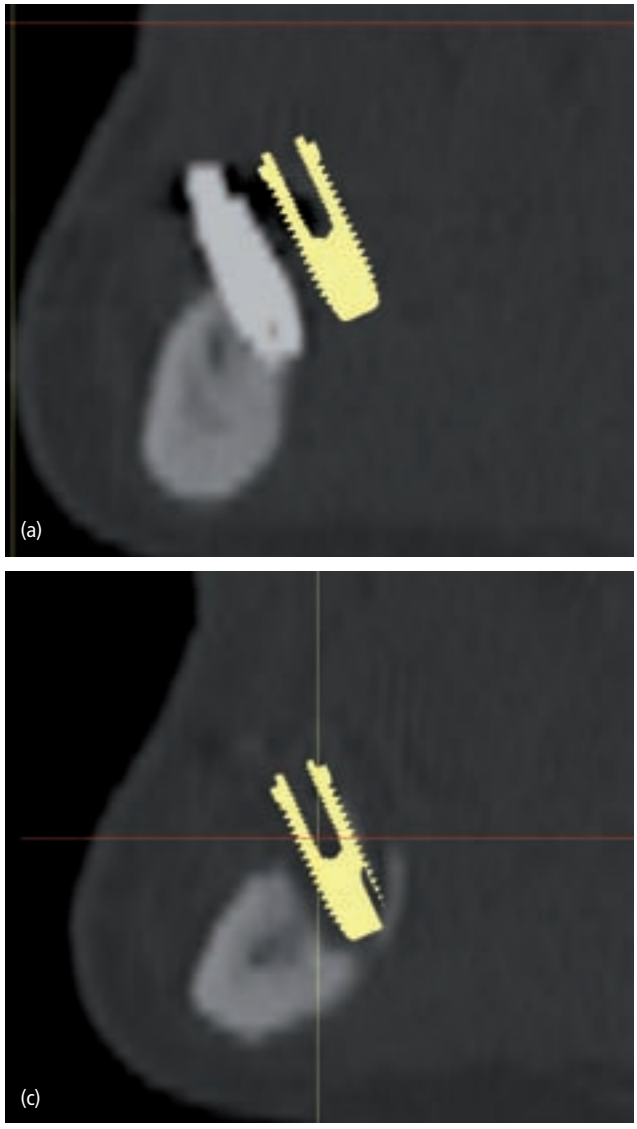


Fig. 4.35 Following the original angulation of the existing implants, a simulated implant was placed parallel at the same angle (a); and then superimposed over the implant for confirmation (b); and then within the radiolucent area where an implant once resided (c).

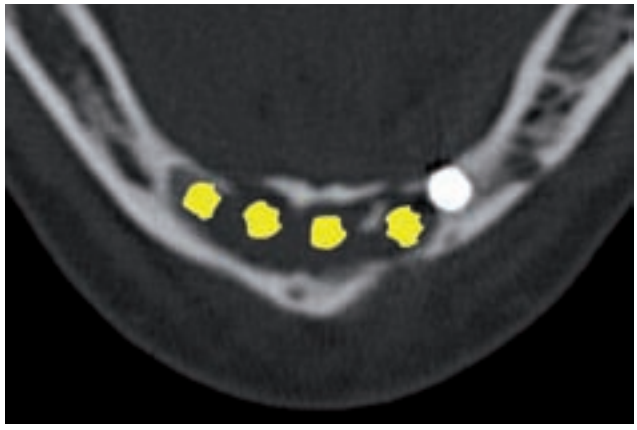


Fig. 4.36 Simulated implants as seen in the axial view.

images are solely used for treatment planning and subsequent placement of dental implants, the results may be catastrophic. Case 4 represented the failure of four implants placed into the anterior symphysis. The failure of one implant is troublesome, but when many implants fail in a manner where bone is destroyed, it is often blamed on factors out of the control of practitioners. The original causative factor was thought to be related to some type of contamination of the implant which would result in cluster failures. Two-dimensional imaging would never have revealed that poor surgical technique was the actual reason for the failures. Using 3D imaging and all of the views afforded by this technology allowed for inspection of the bone post implant failure. The remaining two implants helped to define the original

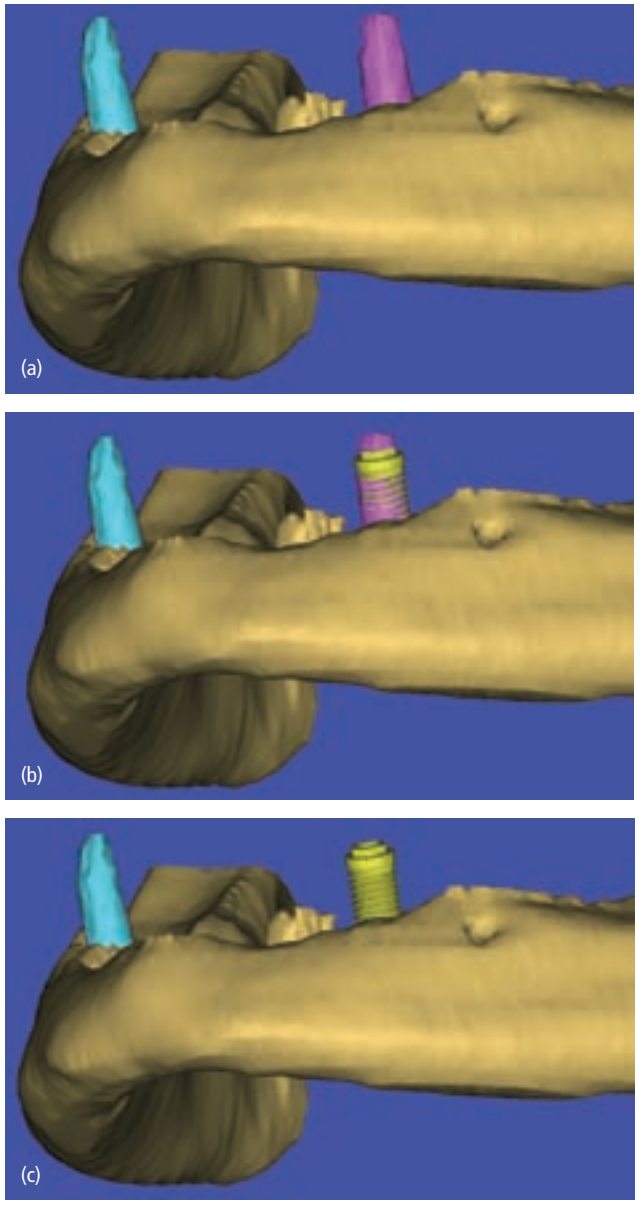


Fig. 4.37 (a–c) To investigate further the reason for the failures, a realistic external hex implant of the same diameter and length was applied to the 3D reconstruction.

angulation of the four implants placed medially. The 3D reconstruction was also a valuable tool in simulating the original placement of the implants, which resulted in perforation of the lingual cortical plate, and subsequent loss of the fixtures.

Placement of implants at unfavorable angles occurs with greater frequency than clinicians, implant manufacturers, and dental laboratories wish to admit. For the mandible, the position of the patient at the time of surgery could be a contributing factor, i.e. lying down or sitting up. The practitioner must be cognizant of the relationship between the inferior border of the mandible, the alveolar crestal bone, and the plane of occlusion.

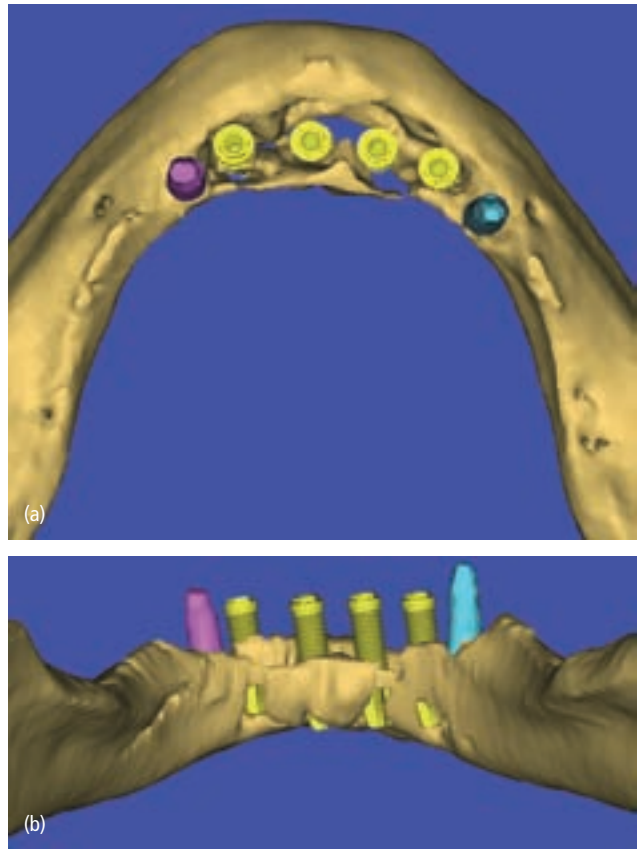
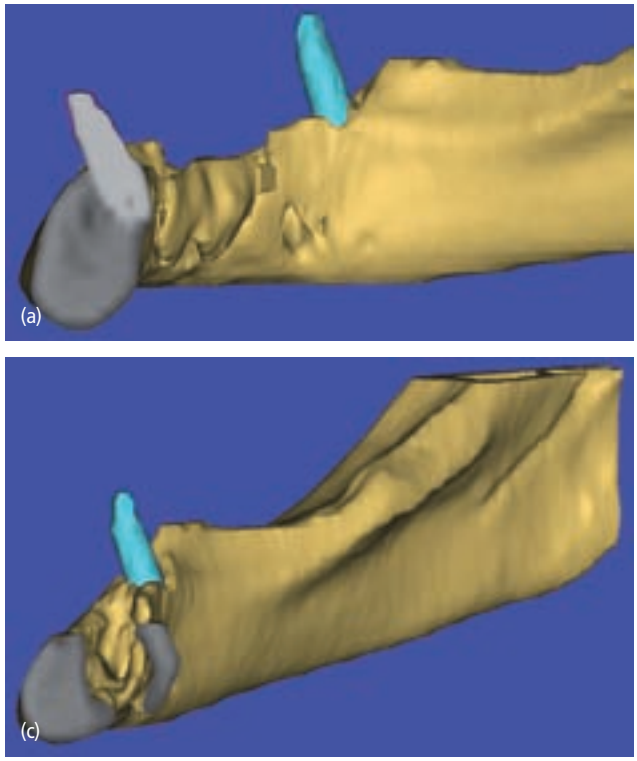


Fig. 4.38 (a) Axial 3D view showing the implant positions; (b) evidence of the lingual perforations is revealed after rotation of the mandible.

With the mouth wide open, it may become easy to become disoriented regarding these planes. Surgical templates based on 3D planning can help to minimize the effect of patient positioning, and aid in the drilling sequence and implant placement within the volume of bone, in the best position to support the desired restoration.

Fortunately, none of the malpositioned implants entered vital anatomic structures, which could have resulted in far more urgent complications, including some which may be fatal. It has been reported in the medical/dental literature that implant placement in the anterior mandibular symphysis can perforate vascular vessels, which can lead to profuse bleeding and obstruction of the airway. In a study of human cadavers, Mardinger *et al.* stated that, "Injury to the vessels in the floor of the mouth is probably more prevalent than reported" (52). They concluded that, "it appears that vessels in the floor of the mouth are sometimes in close proximity to the site of implant placement. Caution should be exercised when placing implants in this area". A CT/CBCT scan allows for inspection of the intraforaminal region, where these vessels reside (Fig. 4.40a). Often the lingual artery can be found at the midline of the symphysis and the genial tubercle in cross-section (Fig. 4.40b).



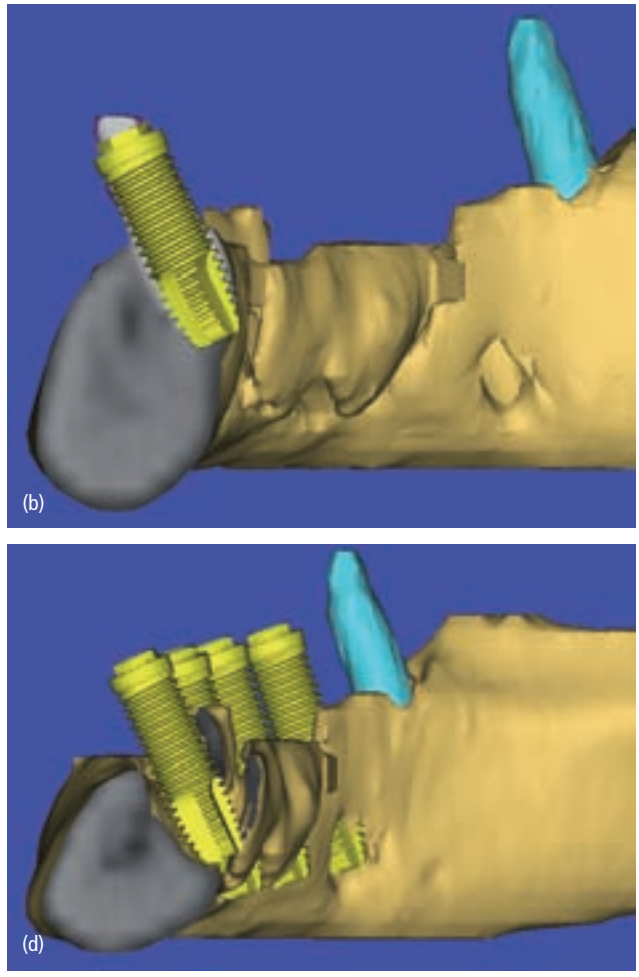
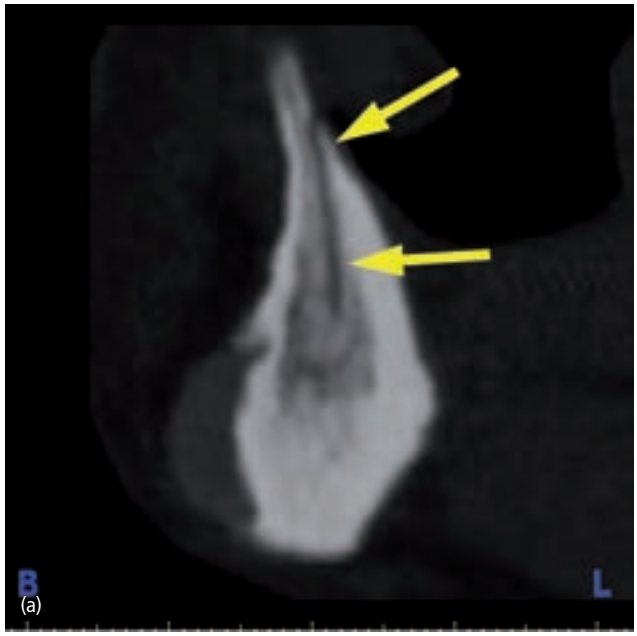


Fig. 4.39 (a–d) 3D cross-sectional slices allowing for superimposition of the realistic implants offering additional information about the original malpositioning.



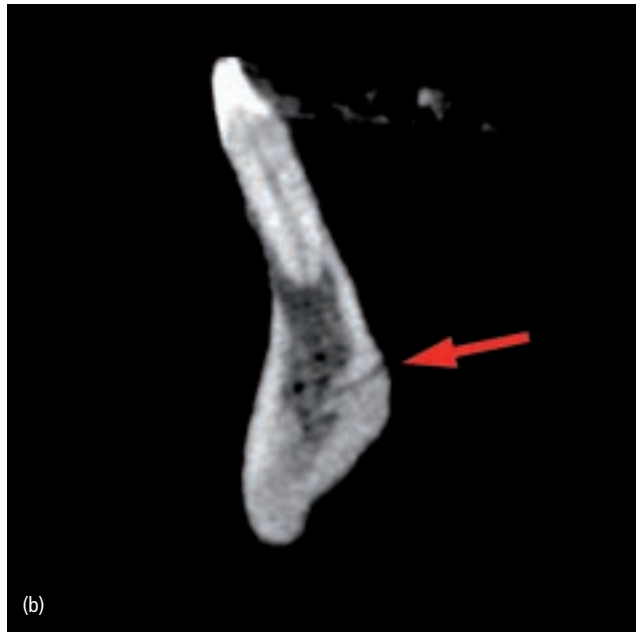


Fig. 4.40 (a) CT/CBCT scan allowing inspection of the intraforaminal region, which may contain vessels and nerves that should be avoided when placing implants; (b) lingual artery found in the cross-sectional view.

If the osteotomy drilling sequence perforates these and other named blood vessels in the region, the sublingual space can fill with blood, which can compromise the airway if it is not immediately determined. Implant surgery near the midline of the mandibular symphysis can be dangerous if these arteries are left undetected (14, 15, 52, 53). Two-dimensional radiography cannot determine these vessels. Therefore, CT/CBCT scans are recommended before implant reconstruction in this anterior mandible.

The path of the inferior alveolar nerve is also difficult to assess with 2D imaging modalities. Two-dimensional panoramic imaging modalities offer a good scout's view of the maxillary–mandibular complex, but cannot determine the spatial positioning of the inferior alveolar nerve. The use of CT/CBCT imaging allows for a more accurate appreciation of the course of the nerve as it enters the mandible through the lingula, and exits at the mental foramen. The distortion factor of panoramic radiology differs among manufacturers and the time between calibrations, and is not equal around the arch. The oval shape of the head is seen as a flat image, and superimposition of anatomic features occurs. If the distortion factor is unknown, and the actual position of the nerve cannot be determined in the vertical or horizontal plane, complications can occur (Fig. 4.41a). If careful depth control is based on faulty information, perforation of the inferior alveolar nerve can lead to permanent paresthesia (Fig. 4.41b). This unfortunate situation could have been avoided with an understanding of the actual location of this vital anatomic structure through 3D imaging modalities.

Conclusions

Implant dentistry is one of the most predictable treatment alternatives that can be offered to patients who are missing teeth. Predictability and accuracy can be greatly enhanced by thorough presurgical diagnosis and treatment planning. Conventional radiographic imaging modalities such as periapical and panoramic radiographs or digital counterparts are limited by their ability to provide clinicians with only a 2D interpretation of existing hard and soft tissue. In addition, these imaging modalities contain inherent distortion factors which may misrepresent bone topography and/or critical vital anatomy, potential grafting and implant receptor sites. However, as recently as 2001, Dula *et al.* (6), when reviewing radiographic assessment of implant patients, concluded that: "Panoramic radiography is considered the standard radiographic examination for treatment planning of implant patients, because it imparts a low dose while giving the best radiographic survey. Periapical radiographs are used to elucidate details or to complete the findings obtained from the panoramic radiograph. Other radiographic methods, such as conventional film tomography or computed tomography, are applied only in special circumstances, film tomography being preferred for smaller regions of interest and computed tomography being justified for the complete maxilla or mandible when methods for dose reduction are followed."

Advances in diagnostic radiologic techniques have dramatically improved with acceptance of CT and CBCT scan technology for dental applications and thus the entire dental implant industry has moved forward

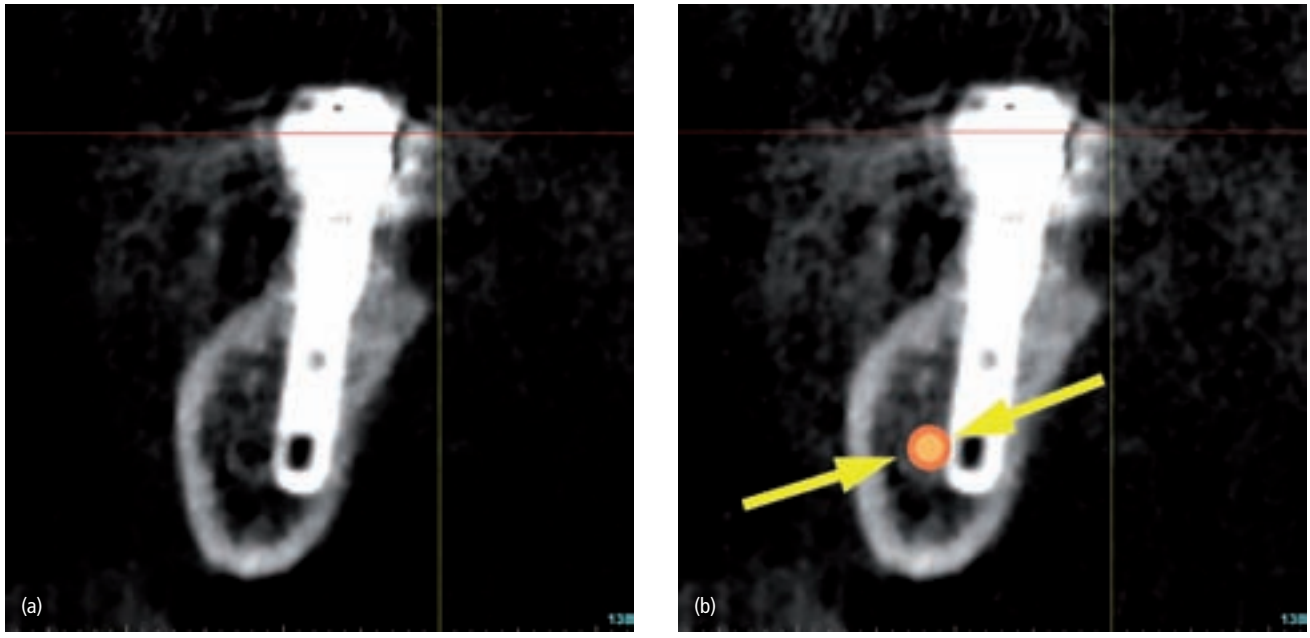


Fig. 4.41 (a) Cross-sectional view illustrating how an implant perforated the inferior alveolar nerve causing paresthesia due to faulty depth control or lack of diagnosis of the position of the inferior alveolar nerve. (b) The nerve is shown in orange.

(54–58). Clearly, the tide has turned in favor of new, lower dose CBCT modalities which offer the most reliable combination of desired images for proper anatomic assessment, diagnosis, and treatment planning. A comparison of conventional digital panoramic orthopantomograms (OPGs) and digital volumetric tomography (DVT) using CBCT found that, "Panoramic views generated from volume data obtained by using the evaluated DVT prototype are comparable to conventional OPTs regarding their diagnostic quality" (59). Further investigation in a follow-up study concluded that, "Radiation dosages for the investigated 3D CB device are closer to those seen in OPG rather than CT imaging. These circumstances confirm a unique information–radiation dose ratio for CB imaging, possibly justifying its larger scale application in implant dentistry " (60).

This chapter has provided several clinical examples which demonstrated the 3D capability of CT, CBCT, and interactive CT as it applied to practical clinical situations. The enhanced diagnostic range of this evolving technology empowers the clinician with the necessary tools to avoid potential complications associated with implant dentistry. This technology has been found to be helpful in expanded areas such as presurgical planning for sinus augmentations, particulate and block bone grafting procedures. Interactive diagnostic software applications allow for enhanced manipulation of data from CT/CBCT to provide state-of-the-art diagnostic tools which create the confidence to benefit both patient and clinician in the quest for achieving predictable results.

Take-home hints

- CBCT/CT scan technology is an extremely valuable diagnostic tool which can provide an accurate assessment of the patient's bone and vital anatomic structures, so helping clinicians to avoid complications.
- Ideally, a scanning appliance should be fabricated in the proper plane of occlusion to be used at the time a CBCT or CT scan is taken.
- CBCT and CT can also aid in the diagnosis and treatment planning of simple to complex bone grafting, and sinus augmentation procedures.
- Three-dimensional imaging can aid clinicians in understanding the zone of the "triangle of bone" to determine viable implant receptor sites, ensure implant placement within the most volume of bone, and prevent malpositioned implants or perforations of the facial or lingual cortical plates of bone.
- Powerful interactive software applications allow further refinement of the CBCT/CT image data, allow for accurate assessment of patient anatomy, provide masking and "selective transparency" to increase visual separation of various structures, and accurate tracings of the path of the inferior alveolar nerve.

References

1. Brånemark PI, Hansson BO, Adell R, Beine J, Lindestrom J, Hallen O, *et al.* Osseointegrated implants in the treatment of the edentulous jaw. Experience from a 10-year period. *Scand J Plast Reconstr Surg* 1977; **16** (Suppl): 1–132.
2. Adell R, Lekholm U, Rockler B, Brånemark PI. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. *Int J Oral Surg* 1981; **10**: 387–416.
3. van Steenberghe D, Lekholm U, Bolender C, Folmer T, Henry P, Hermann I, *et al.* The applicability of osseointegrated oral implants in the rehabilitation of partial edentulism: a prospective multicenter study of 558 fixtures. *Int J Oral Maxillofac Implants* 1990; **5**: 272–81.
4. Sonick M. A comparison of the accuracy of periapical, panoramic, and computed tomographic radiographs in locating the mandibular canal. *Int J Oral Maxillofac Implants* 1994: **9**: 455–60.
5. Rothman SLG. Computerized tomography of the enhanced alveolar ridge. In: Rothman SLG, ed. *Dental applications of computerized tomography.* Chicago, IL: Quintessence, 1998: 87–112.
6. Dula K, Mini R, van der Stelt PF, Buser D. The radiographic assessment of implant patients: decision-making criteria. *Int J Oral Maxillofac Implants* 2001; **16**: 80–9.
7. Goodacre CJ, Kan JYK, Rungcharassaeng K. Clinical complications of osseointegrated implants. *J Prosthet Dent* 1999; **81**: 537–52.
8. Ganz SD. CT scan technology – an evolving tool for predictable implant placement and restoration. *Int Mag Oral Implantol* 2001; **1**: 6–13.
9. Sakakura CE, Morais JA, Loffredo LC, Scaf G. A survey of radiographic prescription in dental implant assessment. *Dentomaxillofac Radiol* 2003; **32**: 397–400.
10. Lam EW, Ruprecht A, Yang J. Comparison of two-dimensional orthoradially reformatted computed tomography and panoramic radiography for dental implant treatment planning. *J Prosthet Dent* 1995; **74**: 42–6.
11. Ganz SD. Advances in diagnosis and treatment planning utilizing CT scan technology for improving surgical and restorative implant reconstruction: tools of empowerment. In: Jokstad A, ed. *Osseointegration and dental implants*. Oxford: Wiley-Blackwell, 2009: 85–94.
12. Freisfeld M, Dahl I A, Jager A, Drescher D, Schuller H. X-ray diagnosis of impacted upper canines in panoramic radiographs and computed tomographs. *J Orofac Orthop* 1999; **60**: 177–84.

13. Harris D, Buser D, Dula K, Grondahl K, Haris D, Jacobs R, *et al.* EAO guidelines for the use of diagnostic imaging in implant dentistry. A consensus workshop organized by the European Association for Osseointegration in Trinity College Dublin. *Clin Oral Implants Res* 2002; **13**: 566–70.
14. Hofschneider U, Tepper G, Gahleitner A, Ulm C. Assessment of the blood supply to the mental region for reduction of bleeding complications during implant surgery in the interforaminal region. *Int J Oral Maxillofac Implants* 1999; **14**: 379–83.
15. Flanagan D. Important arterial supply of the mandible, control of an arterial hemorrhage, and report of a hemorrhage incident. *J Oral Implantol* 2003; **29**: 165–73.
16. Ella B, Sédarat C, Noble Rda C, Normand E, Lauverjat Y, Siberchicot F, Caix P, Zwetyenga N. Vascular connections of the lateral wall of the sinus: surgical effect in sinus augmentation. *Int J Oral Maxillofac Implants* 2008; **23**: 1047–52.
17. Flanagan D. Arterial supply of maxillary sinus and potential for bleeding complication during lateral approach sinus elevation. *Implant Dent* 2005; **14**: 336–9.
18. Kim KD, Park CS. Effect of variable scanning protocols on the pre-implant site evaluation of the mandible in reformatted computed tomography. *Korean J Oral Maxillofac Radiol* 1999; **29**: 21–32.
19. Kalpidis CD, Setayesh RM. Hemorrhage associated with endosseous implant placement in the anterior mandible: a review of the literature. *J Periodontol* 2004; **75**: 631–45.
20. Isaacson TJ. Sublingual hematoma formation during immediate placement of mandibular endosseous implants. *J Am Dent Assoc* 2004; **135**: 168–72.
21. Boyes-Varley JG, Lownie JF. Hematoma of the floor of the mouth following implant placement. *SADJ* 2002; **57**: 64–5.
22. Niamtu J III. Near fatal obstruction after routine implant placement. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2001; **92**: 597–600.
23. Mordenfeld A, Andersson L, Bergstorm B. Hemorrhage in the floor of the mouth during implant placement in the edentulous mandible: a case report. *Int J Oral Maxillofac Implants* 1997; **12**: 558–61.
24. ten Bruggenkate CM, Krekeler G, Kraaijenhagen HA, Foitzik C, Oosterbeek HS. Hemorrhage of the floor of the mouth resulting from lingual perforation during implant placement: a clinical report. *Int J Oral Maxillofac Implants* 1993; **8**: 329–34.
25. Darriba MA, Mendonca-Caridad JJ. Profuse bleeding and life-threatening airway obstruction after placement of mandibular dental implants. *J Oral Maxillofac Surg* 1997; **55**: 1328–30.
26. Rosenfeld AL, Mecall RA. Use of interactive computed tomography to predict the esthetic and functional demands of implant-supported prostheses. *Compend Contin Educ Dent* 1996; **17**: 1125–46.
27. Rosenfeld AL, Mecall RA. Use of prosthesis-generated computed tomographic information for diagnostic and surgical treatment planning. *J Esthet Dent* 1998; **10**: 132–48.
28. Laster WS, Ludlow JB, Bailey LJ, Hershey HG. Accuracy of measurements of mandibular anatomy and prediction of asymmetry in panoramic radiographic images. *Dentomaxillofac Radiol* 2005; **34**: 343–9.
29. White SC, Heslop EW, Hollender LG, Mosier KM, Ruprecht A, Shrout MK. Parameters of radiologic care: an official report of the American Academy of Oral and Maxillofacial Radiology. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2001; **91**: 498–511.
30. Angelopoulos C. Cone beam tomographic imaging anatomy of the maxillofacial region. In: Thomas SL, Angelopoulos C, eds. *Contemporary dental and maxillofacial imaging. Dental Clinics of North America*, Vol. 52. Philadelphia, PA: Elsevier, 2008: 731–52.
31. Jacobs R, Mraiwa N, Van Steenberghe D, Sanderink G, Quirynen M. Appearance of the mandibular incisive canal on panoramic radiographs. *Surg Radiol Anat* 2004; **26**: 329–33.
32. Klein M, Cranin AN, Sirakian A. A computerized tomographic (CT) scan appliance for optimal presurgical and pre-prosthetic planning of the implant patient. *Prac Periodont Aesthet Dent* 1993; **5**: 33–9.
33. Ganz SD. Presurgical planning with CT-derived fabrication of surgical guides. *J Oral Maxillofac Surg* 2005; **63** (Suppl 2): 59–71.
34. Kim KD, Jeong HG, Choi SH, Hwang EH, Park CS. Effect of mandibular positioning on preimplant site measurement of the mandible in reformatted CT. *Int J Periodont Restor Dent* 2003; **23**: 177–83.
35. Amet EM, Ganz SD. Functional and aesthetic acceptance prior to computerized technology for implant placement. *Implant Dent* 1997; **6**: 193–7.
36. Israelson H, Plemons JM, Watkins P, Sory C. Barium-coated surgical stents and computer-assisted tomography in the preoperative assessment of dental implant patients. *Int J Periodont Restor Dent* 1992; **12**: 52–61.
37. Marino JE, Arenal AA, Ceballos AP, Vasquez IP, Diaz GI. Fabrication of an implant radiologic-surgical stent for the partially edentulous patient. *Quintessence Int* 1995; **26**: 111–14.
38 Basten CH, Kois JC. The use of barium sulfate for implant templates. *J Prosthet Dent* 1996; **76**: 451–4.
39. Basten CH. The use of radiopaque templates for predictable implant placement. *Quintessence Int* 1995; **26**: 609–12.
40. Borrow W, Smith JP. Stent marker materials for computerized tomograph-assisted implant planning. *Int J Periodont Restor Dent* 1996; **16**: 61–7.
41. Ganz SD. Computer aided technology for implant prosthodontics. *57th AAID Annual Meeting*, Manchester Grand Hyatt Hotel, San Diego, CA, October 30, 2008.
42. Ganz SD. Computerized planning: generation of CAD CAM structures and surgical guides to provide patients with immediate provisionalization and minimally invasive surgery. *AAOMS Annual Implant Conference*, Sheraton Chicago Hotel & Towers, December 5, 2008.
43. Ganz SD. Advanced case planning with SimPlant. In: Tardieu P, Rosenfeld A, eds. *The art of computer-guided implantology*. Chicago, IL: Quintessence, 2009: 193–210.
44. Ganz SD. Techniques for the use of CT imaging for the fabrication of surgical guides. *Atlas Oral Maxillofac Surg Clin North Am* 2006; 14: 75–97.
45. Pikos MA. Complications of maxillary sinus augmentation. In Jensen OT, ed. *The sinus bone graft*, 2nd edn. Chicago, IL: Quintessence, 2006: 103–13.

46. *Mosby's medical dictionary*, 8th edn. Elsevier, 2009.
47. Ganz SD. The triangle of bone – a formula for successful implant placement and restoration. *Implant Society* 1995; 5(5): 2–6.
48. Ganz SD. Mandibular tori as a source for onlay bone graft augmentation. A surgical procedure. *Pract Periodont Aesthet Dent. The Implant Report* 1997; 9: 973–82.
49. Ganz SD. The reality of anatomy and the triangle of bone. *Inside Dentistry* 2006; **2**(5): 72–77.
50. Ganz SD. Using interactive technology: in the zone with the triangle of bone. *Dent Implantol Update* 2008; **19**(5): 33–8; quiz 1.
51. Chappuis V, Suter VGA, Bornstein M. Displacement of a dental implant into the maxillary sinus: report of an unusual complication when performing staged sinus floor elevation procedures. *Int J Periodont Restor Dent* 2009; **29**: 81–7.
52. Mardinger O, Manor Y, Mijiritsky E, Hirshberg A. Lingual perimandibular vessels associated with life-threatening bleeding: an anatomic study. *Int J Oral Maxillofac Implants* 2007; **22**: 127–31.
53. Bavitz BJ, Harn SD, Hansen CA, Lang M. An anatomical study of mental neurovascular bundle–implant relationships. *Int J Oral Maxillofac Implants* 1993; **8**: 563–7.
54. Rosenfeld A, Mandelaris G, Tardieu P. Prosthetically directed placement using computer software to insure precise placement and predictable prosthetic outcomes. Part 1: Diagnostics, imaging, and collaborative accountability. *Int J Periodont Restor Dent* 2006; **26**: 215–21.
55. Ganz SD. Computer-aided design/computer-aided manufacturing applications using CT and cone beam CT scan technology. In: Thomas SL, Angelopoulos C, eds. *Contemporary dental and maxillofacial imaging*. Dental Clinics of North America, Vol. 52. Philadelphia, PA: Elsevier, 2008: 777–808.
56. Guerrero ME, Jacobs R, Loubele M, Schutyser F, Suetens P, van Steenberghe D. State-of-the-art on cone beam CT imaging for preoperative planning of implant placement. *Clin Oral Investig* 2006; **10**: 1–7.
57. Ganz SD. Restoratively driven implant dentistry utilizing advanced software and CBCT: realistic abutments and virtual teeth. *Dent Today* 2008; **27**: 122, 124, 126–7.
58. Ganz SD. Defining new paradigms for assessment of implant receptor sites – the use of CT/CBCT and interactive virtual treatment planning for congenitally missing lateral incisors. *Compend Cont Educ Dent* 2008; **29**: 256–67.
59. Mischkowski RA, Ritter L, Neugebauer J, Dreiseidler T, Keeve E, Zöller JE. Diagnostic quality of panoramic views obtained by a newly developed digital volume tomography device for maxillofacial imaging. *Quintessence Int* 2007; **38**: 763–72.
60. Dreiseidler T, Mischkowski RA, Neugebauer J, Ritter L, Zöller JE. Comparison of cone-beam imaging with orthopantomography and computerized tomography for assessment in presurgical implant dentistry. *Int J Oral Maxillofac Implants* 2009; **24**: 216–25.

Chapter 5

Implant fractures: etiology, prevention, and treatment

Steven E. Eckert DDS, MS, FACP *and Thomas J. Salinas* DDS, FACP

Introduction

All forms of dental therapy are associated with risks and benefits. Selection of a specific form of intervention is based on a logical ratio of the two, with risks being low and benefits being great. In dental implant therapy there is a logical hierarchy of complications that define the risk portion of this ratio. Complications may be described as minor, moderate, or severe. Minor complications are those that can be quickly resolved with little morbidity or expense. Moderate complications are events that may be resolved without major expense but demand more cognitive and physical intervention to reverse the complication. Finally, severe complications are those that require replacement of critical components and result in a level of patient morbidity.

Based on this complication hierarchy, one of the most severe of all complications is the fracture of a dental implant that has undergone osseointegration and is used to support a dental prosthesis. When such a fracture occurs the prosthesis is adversely affected by the loss of a supporting implant. Since fracture is often associated with sustained or intermittent force application, the loss of one implant may condemn the prosthesis to imminent failure. The remnants of the implant, remaining integrated with bone, must be surgically resected and are then subject to postsurgical morbidity that could include pain, infection, and possible jaw fracture. Indeed, this complication carries with it a litany of adverse outcomes.

This chapter presents factors related to incidence, predisposing factors, and methods to diminish the risk of implant fracture.

Incidence

The fracture of osseointegrated implants is a relatively uncommon occurrence. A clinical study of 4937 implants (grade 1 titanium turned screw design) used to support dental prostheses demonstrated fracture occurring in 0.6% of all implant placements, with a lower incidence in edentulous jaws (0.2%) and more frequent occurrence in partially edentulous jaws (1.5%) (1) (Fig. 5.1). Once encountered, however, this is a major complication that usually mandates the removal of the remnants of the original implant. Subsequent to implant removal, an additional implant would need to be placed and the dental prosthesis would require refabrication.

Review of this study identified factors that may influence the risk of implant fracture. Since all implants in the study were commercially pure grade 1 titanium implants, it may be postulated that the incidence could be lower at present, considering that many implants are made of higher grade titanium or titanium alloy, both of which achieve appreciably higher ultimate tensile strength than grade 1 titanium. It was also observed that all implant fractures occurred in implants of 3.75 mm diameter commercially pure titanium (1). Finally, fractures were preceded by repeated screw joint complications. Considering these factors, slight alterations in material, dimensions, and maintenance protocols could positively influence clinical outcomes.

Etiology

The observation that fractures are encountered more frequently in the partially edentulous jaw should not be surprising. When comparing the edentulous jaw to the partially edentulous jaw it is clear that the arrangement of implants in the edentulous jaw creates a more favorable curvilinear pattern. In contrast, implants in the partially edentulous jaw are generally arranged in a rectilinear pattern (Table 5.1). This is particularly true in the posterior portions of the partially edentulous jaw where the magnitude of force generation is greatest. Even though clinicians may attempt to create a slight offset to the arrangement of implants, this offset is limited by the need to place the implants within the anatomic confines of the prosthetic restoration (2). Early biomechanical design analyses performed by Skalak (3–5) suggest a sharing of forces by implants in the edentulous arch, but subsequent analyses that considered the partially

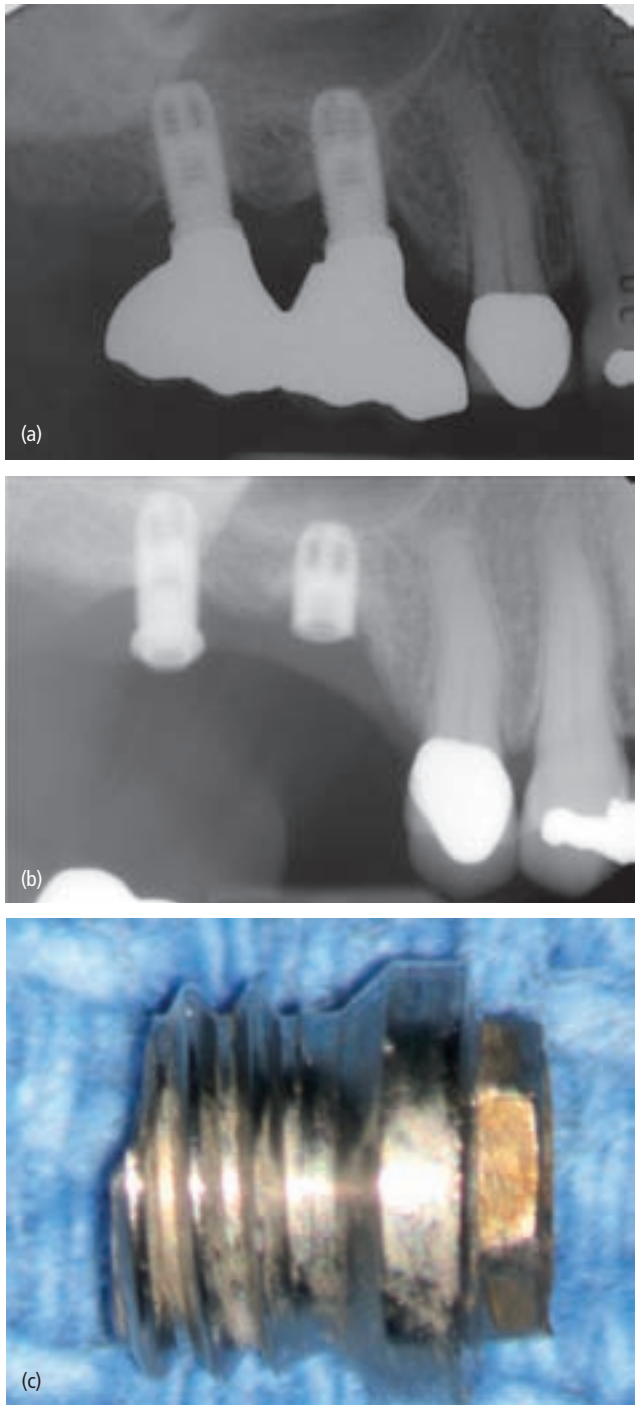


Fig. 5.1 (a–c) Turned commercially pure titanium implant (3.75 mm) supporting screw-retained fixed prosthesis which fractured after 18 years. The failure pattern in (c) shows characteristic topography of fatigue failure. The distal segment of the implant was removed and replaced with a wide platform implant. (Courtesy of Phil Sheridan.)

edentulous restorations suggested different levels of force distribution (6–8).

Originally introduced for edentulous patients, endosseous implants are currently used in the management of partially dentate patients. The implant arrangement used to support dental prostheses for edentulous patients is dramatically different than that of partially dentate patients. This situation could contribute to differences in the clinical performance of both implants and prostheses. Complications seen in partially edentulous patients piloted the development of alternative implant and prosthetic component designs specifically created to address the needs of the partially edentulous patient.

Table 5.1 Characteristics of implant prosthetic design

	Edentulous	Partially dentate
Orientation of implants	Curvilinear arrangement	Rectilinear arrangement
Relationship of prosthetic tooth to implant position	Variable	Correlated
Esthetic/hygienic design	Raised (mandible) Tissue contact/ridge lap (maxilla)	Tissue contact/ridge lap

Over the past several decades the general shape of implants has changed dramatically. The classic implant designs, using threaded parallel walls with external prosthetic connections at the superior aspect of the implant, have gradually diminished in clinical use. Today, implant designs more frequently use internal prosthetic connections that are described as having improved mechanical stability. Currently, many of these implants have tapered configurations. These changes have occurred to address the perceived superior stability of prosthetic connections with internal connections and perceived benefits relative to surgical placement of implants. In addition, tapered implant designs have been introduced to address concerns over a mismatch between the shape of the natural tooth root and the replacement endosseous implant.

Previous studies describing implant fracture in large clinical trials were performed using external hex implants. Anecdotal reports of internal hex failure with fracture of the vertical walls of the implant are being presented with increasing incidence at professional meetings. Unfortunately, at present there are no studies that demonstrate the incidence of implant fracture with internal connections. Depending on the thickness of the implant walls and the presence or absence of a bevel at the restorative platform, it is certainly possible that failure of an internal connection could pose a risk similar to or greater than that seen with the externally hexed implants.

The changes in abutment screw design after June 1990 resulted in the creation of screws with effective thread engagement at the apical aspect. Therefore, upon torque application to abutment screws, the most coronal two or three implant internal threads are placed in compression, resulting in stress concentration to the platform of the implant. This may be a consideration when the

implant is placed under repeated function with a portion of the implant under compression. Some implant systems may withstand these and other forces well based on the alloys used, whereas others may fail by virtue of either static fatigue (i.e. the result of a specific load that exceeds the yield strength of the alloy) or dynamic fatigue (i.e. the result of a number of loads that exceed the elastic limit of the alloy, producing a defect in the alloy).

Fractures are often preceded by repeated abutment or prosthetic gold screw loosening (Fig. 5.2a–d). In many of these patients, parafunctional activity and associated bone loss are demonstrated (9). Prosthesis misfit may also be correlated with implant fracture. This can occur when a casting is not adapted to the underlying transmucosal abutment or implant or when there has been physical distortion of the superior surface of the abutment or implant. Whatever the etiology of implant fracture, it is the primary goal to design prostheses with fail-safe mechanisms for shared occlusal loads, such as stress directors which give an indication that the applied loads may exceed the tolerance of the prosthesis–implant complex.

Bone loss versus abutment screw configuration

Bone loss may be a factor that is associated with implant fracture. There is a specific pattern of bone loss often seen in cases where implants have undergone fracture (8). In cases where this bone loss advances to the level past engagement of the abutment screw, this area seems to be most vulnerable to cyclic fatigue as it is the thinnest portion of the implant. In addition, the modulus of elasticity (MOE) of titanium is in the order of ten times higher than that of bone, thereby predisposing both to shear forces. Bone, being a dynamic tissue, is capable of adaptation to the forces placed upon it within the normal confines of the prosthesis–implant complex. However, outside of what would be considered normal, the metal may undergo cyclic fatigue and ultimately failure under the bending forces placed upon it. Frequently, this seems to occur at the same level as the base of the osseous defect, making this a fulcrum point for bending forces. Indeed, microstructural analysis has demonstrated that fragments from fractured implants showed patterns compatible with fatigue failure.

Although early theories suggest that bone loss makes the implant more susceptible to fracture (8), it is possible that bone loss may be secondary to microfracture of the alloy microstructure and be a sequela of the fracture itself (1). Retrograde infection of the site from the intaglio surface of the implant through the fracture may induce inflammation and be responsible for some of the bone loss. Often, commercially pure titanium will tear under chronic cyclic overload and create a notch. If a defect notch starts at an interface and has a degree of micromotion or acts as a conduit for inflammatory mediators, it would be evident that bone loss would ensue. As a result of further propagation, the bone loss becomes a secondary factor for initiation by the microfracture.

Iatrogenic implant placement or manipulation

Cross-threading the internal threads of the implant may also lead to component complication, increasing the potential for fracture. This may occur either because the cross-threading leads to more frequent screw loosening or because the cross-threading is rectified through the use of a tap to recreate the appropriate threads, thereby removing some material from the internal surface of the implant. Gentle, deliberate placement of healing abutments, impression components, and restorative abutments will preserve the pristine nature of these mechanical connections, avoiding the potential for an unstable connection.

Manufacturing defects

Defects in the raw materials and in the manufacturing process are certainly possible when implants are made. Clinicians are cautioned to purchase implants from manufacturers who demonstrate good manufacturing practices in keeping with International Organization for Standardization (ISO) or Food and Drug Administration (FDA) standards.

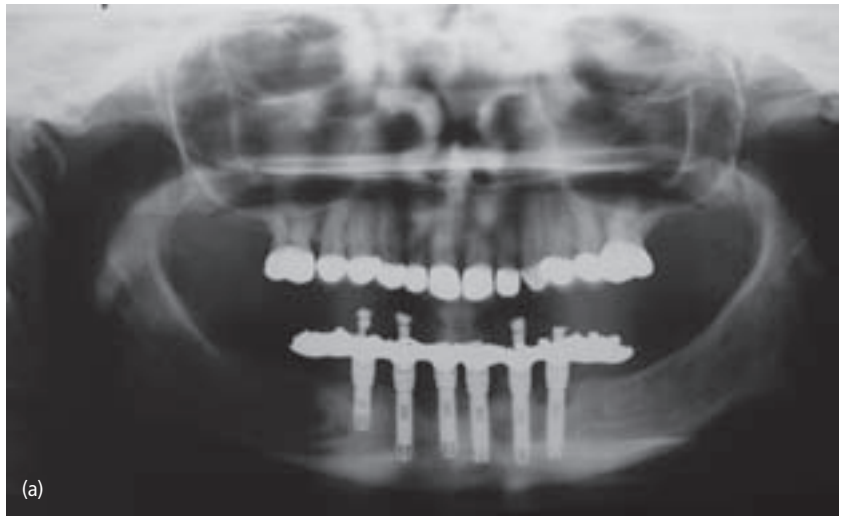
Although clinicians may fail to appreciate the need for product recalls, such recalls may indicate a manufacturer's attention to detail. Clinicians should be diligent in maintaining product lot numbers and patient records to ensure an appropriate response in the event of such a recall.

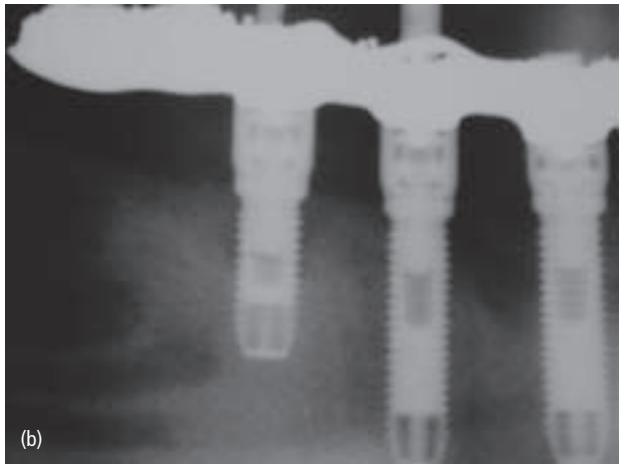
Biomechanics

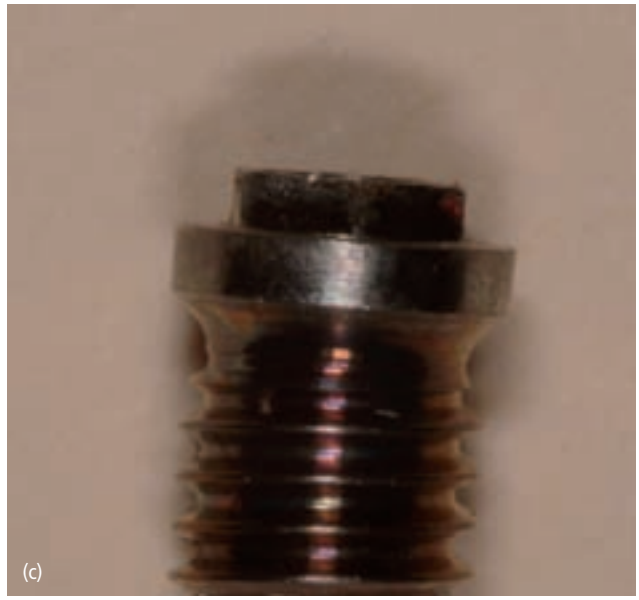
It has been documented that the human bite force potential can exceed several hundred Newtons of force in the molar region, thereby transferring a high magnitude of force to the implant. Typically, fractured implants are found in the molar areas where this force potential is quite high. Other sources of fractures may be adjacent to cantilever extensions where force application has the potential to cause bending moments, precipitating fracture. Limitations in the length and use of cantilever extensions may be judicious where concern exists over bite force potential.

Patient-related factors

Parafunctional activities can lead to excessive forces on the implants. In addition to bruxism and clenching, some







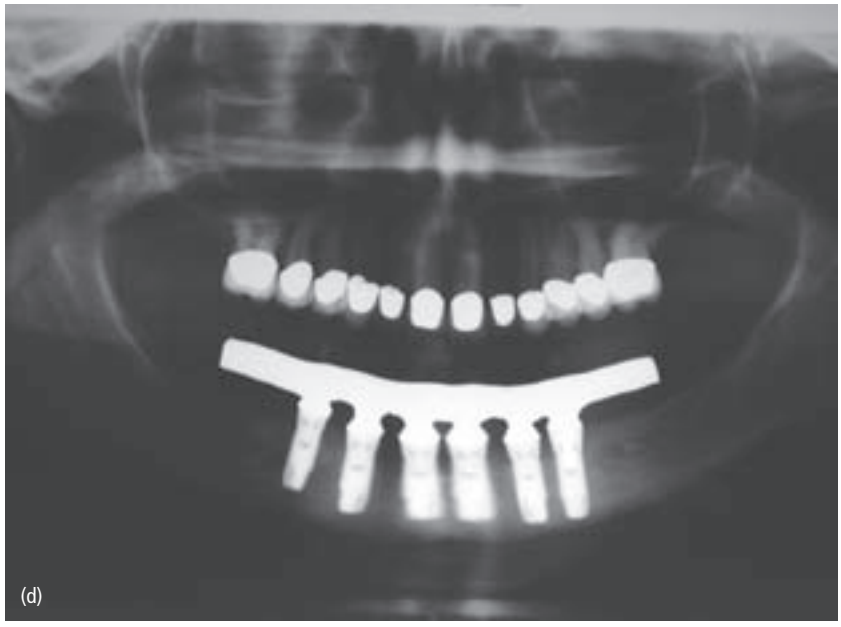


Fig. 5.2 (a, b) Six regular platform Brånemark first generation implants, supporting fixed osseointegrated prostheses with extensive bone loss with multiple prosthetic screw loosening. After 15 years of service most distal implants were symptomatic; after retrieval of the prosthesis, the proximal portions of the implants were retrieved. (c) Retrieved proximal implant segment. (d) Case retreated with six wide platform implants.

patients simply chew with excess force. If parafunctional activities are noted it is appropriate to provide the patient with a protective occlusal guard that can be used during sleeping hours. Likewise, protective guards could be used during waking hours for patients who repeatedly clench or grind during these times. Counseling may be beneficial for patients who chew with excessive force. There is, however, no panacea for this patient group. It may be more appropriate for patients in this category to consider a greater number of implants to share in the functional load and to consider implants of larger diameter, thereby making the implant more resistant to the forces that could cause fracture.

Prevention

Dental implants must be fabricated from materials that are biocompatible. In addition, the materials used for dental implants must maintain mechanical properties sufficient to resist anticipated forces within the stomatognathic system. Materials must obviously withstand masticatory force, but also must be capable of performing under parafunctional loading conditions as factors such as bruxism, which can lead to higher force applications for longer periods than would normally be experienced with masticatory force.

Since osseointegration was originally demonstrated with commercially pure titanium implants, type 1, and since these implants generally performed well over a period of 15 years (10), it seems logical to assume that the strength characteristics of type 1 commercially pure titanium are routinely adequate for endosseous implants that undergo the process of osseointegration. All other forms of commercially pure titanium, types 2–4, exhibit strength characteristics that are equal to or greater than those of type 1. Likewise, the titanium alloys generally provide improved mechanical properties relative to type 1 commercially pure titanium.

A variety of different materials is used in the fabrication of endosseous implants. Most implants use commercially pure titanium or alloys of titanium, aluminum, and vanadium. Dental implants can be made from any of the four forms of commercially pure titanium, which vary in their concentration of iron and oxygen, but are largely 99% pure titanium. Commercially pure titanium has traditionally been the material of choice for use in dental implant fabrication; as such, this material has received the highest level of scientific scrutiny as there are more published research studies related to commercially pure titanium implants than to any other material. The strength of titanium and titanium alloys is largely sufficient for their use as supporting mechanisms for dental prostheses.

The yield strength in the four forms of commercially pure titanium varies from 170 to 480 MPa, with an MOE approaching 114 GPa. In general, the lower the grade or type the lower the MOE, yield strength, and resistance to fatigue failure (Table 5.2). The microstructure of titanium may assume a mixture of phases: either alpha, beta, or alpha–beta. The beta form of crystal lattice tends to be stronger than the alpha phase and is made more resistant to deformation by heat treatment of the alloy. Certain elements (iron, vanadium, and chromium) added to the titanium facilitate crystal formation to the beta phase, making it ideal for heat treatment.

Table 5.2 Flexural strength of various implant materials

Material	Yield strength[a] (MPa)	Tensile strength[b] (MPa)
Commercially pure titanium grade 1	172	241
Commercially pure titanium grade 2	276	345
Commercially pure titanium grade 3	379	448
Commercially pure titanium grade 4	483	552
Ti-6Al-4V	828	897

Data from American Society for Testing and Materials (ASTM International Standards).

[a] The stress at which the material is changed in shape to permanent strain.

[b] The maximum stress that a material can withstand before failure in tension.

Wrought titanium (90%), aluminum (6%), and vanadium (4%) alloy, often described as Ti-6Al-4V, is one of many titanium alloys that has comparably higher yield strength (900 MPa), although its MOE is similar to commercially pure titanium. It has the ability to endure high cyclic elastic deformation yet maintain its integrity. Heat treatment of Ti-6Al-4V alloy has the same effect of producing a fine-grained microstructure that has considerable resistant properties to plastic deformation. Although no difference has been identified between the osseointegration of Ti-6Al-4V and that of commercially pure titanium, differences in prostaglandin, interleukins, and tumor necrosis factor release have been investigated, noting minute differences in bone loss. In general, commercially pure titanium and titanium alloys are highly biocompatible and can be used with an equal degree of success/survival. Although no studies have been published on the fatigue failure of Ti-6Al-4V wrought implants (11), attention is often directed towards the effects of the oral environment rather than the material behavior *in vivo*.

General implant shape

The shape of implant to be used for prosthetic support has undergone investigation to ensure that its shape allows a compressive load to bone. Biomechanically,

bone accepts forces in compression rather than shear and tension. Current biomechanical designs of implants place the load in a maximum of compression rather than shear. Introduction of a three-dimensional porous surface implant has been successful in providing higher bone/metal shear strengths as well as an improved stress transfer from the implant to the bone interface, an improved stress distribution from the implant to the bone, and resultant lower stresses to the implant.

The consideration of thread height and width seems to be important when the implant is placed in cancellous bone and when loaded non-axially. Finite element analyses indicate stress reduction when the height approaches 0.34–0.5 mm and the width 0.18–0.30 mm (12), but the long-term effect of these idealized thread dimensions relative to implant resistance to fracture remains unknown. Engineering designs may predict performances but, unfortunately, it is only clinical testing that can confirm these hypotheses.

Implant diameter is of prime importance for resistance to fracture since the fracture resistance increases proportionally to the increase in radius of the implant multiplied to the fourth power (13). As implant diameter increases, however, there is a proportionate reduction in stress distribution to the surrounding bone which may cause stress shielding and an adverse bone response. Concurrently, it would seem apparent that small-diameter implants have a high stress transfer to the bone, perhaps increasing the risk of fracture. Although this statement seems logical there are few reports in literature other than case reports of failure of narrow-diameter implants, perhaps owing to their primary utilization in the anterior portions of the oral cavity.

Surgical placement

Care should be taken to minimize torsion to the implant–driver interface, which could potentially distort the platform connection. Implant placement in type IV bone should be preceded by tapping the bone instead of relying on the implant to tap the osteotomy. Some manufacturers have cautioned exceeding the recommended torque on surgical placement to reduce the potential for fracture (Fig. 5.3a–c).

Preservation of bone surrounding the implant has been approached with theories of strategy for redesigning the abutment–implant connection. Minimizing inflammation by placing the abutment platform connection internal to the external implant surface has become a popular paradigm, although it is not scientifically proven. Studies are ongoing with the so-called platform switched implant, but the long-term implications towards force concentration at the platform level of the implant, which could lead to a higher risk of implant fracture, are unlikely to be published for years to come.

The success of osseointegrated implants in bone types I, II, and III (using Leckholm and Zarb's classification of bone) has been noted to be different than success in type IV bone (14). As such, these locations throughout the dental arch will receive force transmission differently based on these densitometric variances. Non-axial or lateral force transmission for implants in dense cortical bone typically occurs where the implant collar meets the bone. In cancellous bone, lateral forces are mostly isolated at the apical portions of the implant, somewhat dependent on thread configuration (15). In cases where implants are placed in the posterior mandible and connected rigidly, the degree of mandibular flexure should be taken into account as this can be significant. Lateral force transmission upon mandible opening and closing can potentially introduce shear forces to the prosthesis implant connection. One potential way to address the issue is to separate segments of the prosthesis as free-standing or non-engaging for the most distal implants.

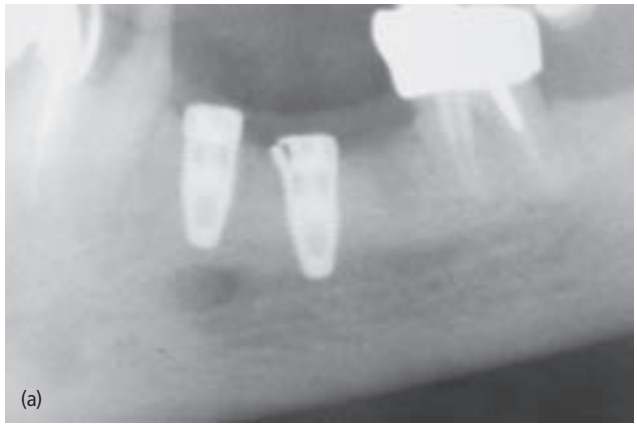
Prosthetic design

Recognizing that implant fracture can occur, it is the clinician's responsibility to use components designed to avoid such complications. Likewise, it is important to design prostheses that are resistant to implant fracture. Finally, it is critical that identified risk factors be addressed in long-term clinical follow-up.

Stress transfer in fixed or removable prostheses has been the subject of considerable scrutiny. The status of the patient's dentition, whether patients are edentulous or partially dentate, may affect stress distribution among the supporting implants.

Force vectors in patients restored with either fixed or removable prostheses differ according to materials, implant distribution, and overall design. Force application to the implants is not affected by the material used in the prosthesis, in that a 100 N force applied to a metal restoration, ceramic restoration, or acrylic restoration will transmit the same 100 N to the underlying implants. The distribution of these forces to the implants may differ on the basis of the material but the total force on the combined implant supporting system is the same. Materials do, however, behave differently relative to the dissipation of impact forces. Stiffer materials, such as ceramics, will transmit forces to the implants more rapidly, while more resilient materials, such as acrylic resins, transmit forces more slowly, sometimes described as a dampening of the forces (16, 17).

Other factors that have yet to be comprehensively evaluated include the use of materials such as high-strength ceramics as implant abutments. These materials have different abrasive potential that may introduce advanced degrees of wear to the implant platform under function. What further influence this has on the integrity



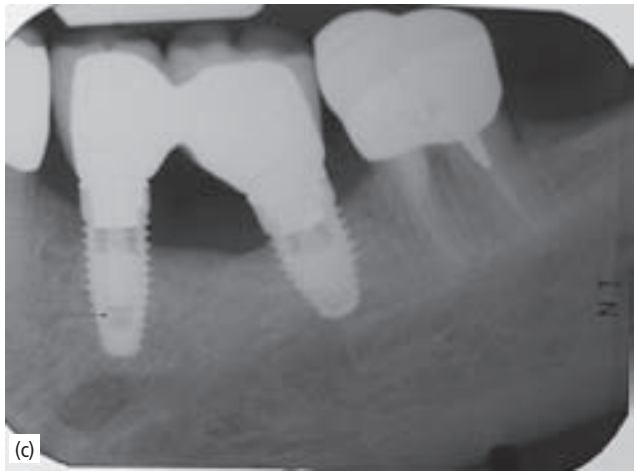


Fig. 5.3 (a) Radiograph showing fractured internal connection and fraying of the implant interface that occurred during implant placement in type I bone. (b) Retrieved implant and defect along the implant platform. (c) Radiograph taken 2 years after completion of a splinted restoration on the replaced implant. (Courtesy of Stuart Froum.)

of the implant platform remains to be determined. Titanium can develop facets under certain loading conditions with repeated stresses over time, which may be a predictor of prosthetic complications. With the predictors of implant fractures being repeated prosthetic complications, there may be a relationship between changes to the implant platform and implant fracture potential.

Although early publications on implant performance suggested the advantage of force-dampening materials, there is no consistent evidence in the literature to suggest that one material used for restoration performs any better than another relative to implant survival or the fracture resistance of implants. Materials may differ in clinical performance relative to material wear, fracture, or cosmetic appearance, but these factors do not relate to changes in the risk of implant fracture.

Prosthodontic scenario

Bite forces have been classically described as being greater in males than in females, by 30–40%. This factor should be considered when planning treatment, to attain evenly distributed forces. Prosthetic design, implant diameter, arch location, implant number, and occlusal morphology may demand different thought processes depending on gender.

Placement strategies upon implant insertion should also be considered, to facilitate sound force transfer to maximize the resistance of each implant in relation to its shared load in function. Spatial relationships when restoring multiple adjacent implants should be planned; for instance, a staggered position will be more resistant to non-axial directed forces than a straight-line configuration. However, it may not be feasible to consider such arrangements where bone is limited or where planned tooth positions or esthetics dictate a more linear arrangement.

The diameter of an endosseous implant rarely matches the greatest diameter of the natural tooth that is being replaced. Often it is the case with molar tooth replacement that the tooth size is quite different than that of the implant platform diameter. Careful attention should be paid to occlusal contacts in these cases. Forces should be centered within the prosthetic tooth and should be directed along the long axis of the implant. When this is not possible occlusal anatomy should be flattened to reduce lateral forces from food impaction upon the occlusal surface of the restoration.

The objective of treatment is to use the appropriate implant, made of the appropriate material, of the appropriate dimensions, with the appropriate transmucosal abutment, using the appropriate abutment screw design to retain a prosthetic restoration that appropriately considers all factors related to anticipated forces and patient behavior. When all factors are considered, implant fracture should be a rare occurrence.

Occlusal overload

The maximum bite force potential has been estimated to vary between 600 and 800 N in the posterior areas of the dental arch. From a purely mechanical standpoint, the closer the forces are applied to the temporomandibular joint the greater they will be. The situation relates to the class III lever system encountered in the jaw. This places the posterior implants at higher risk for excessive force application. Although there are no clinical studies that demonstrate a significantly higher risk of implant fracture in the posterior portions of the oral cavity, this is likely a statistical anomaly related to the low fracture rate of implants in general.

Orthognathic and craniofacial classifications can also have an influence on bite force. Typically, patients with a dolichocephalic (long face) or orthognathic classification, i.e. class II jaw relations, have less force-generating potential than those with a brachycephalic or class III type. Some of this potential relates to pure mechanics and vectors of force which are directed more efficiently to provide force transfer. Other factors are due to gender and ethnicity, with males exerting greater bite force potential, exceeding females by another 30–40% of maximal force. These differences have also been well documented and should be considered when planning treatment.

There appear to be no evidence-based guidelines for the development of any specific occlusal schemes for implant prosthodontics (18). There are, however, practical factors that influence the occlusion of implant-supported prostheses. One concern is that implant-supported prostheses are retained mechanically. This retention is accomplished through the use of screw retention or cement retention, but even cement-retained restorations generally have a screw-retained transmucosal element known as the abutment. Lateral forces on the screw-retained components could overcome the clamping force, thereby resulting in screw loosening. To prevent this situation every effort should be made to eliminate or minimize lateral forces on the implant. This can be accomplished by maximizing the offset of implants when three or more implants are used, flattening the occlusal anatomy, centralizing occlusal contacts, minimizing cantilevers in all dimensions, and aligning implants perpendicularly to the occlusal surface (19, 20).

Consequently, it seems logical to address screw loosening aggressively for appropriate management of the occlusion, to eliminate lateral forces if and when loosening occurs.

Anterior guidance on implant restorations without adjacent teeth can be considered when a number of implants will allow mutual support for establishing this pathway. It may be beneficial to test this with provisional restorations before completing the final restorations. In many cases, this scenario proves problematic and creates unfavorable force transfer to the implant. Although most implant fractures occur at posterior tooth sites, attention to anterior guidance with assisted contact of the adjacent teeth is preferred.

Placement of implants should be done in a manner consistent with both the manufacturer's suggestions and the clinician's experience.

Treatment

Fracture of an osseointegrated implant is a catastrophic event necessitating removal of the residual implant fragments. Failure to do so may result in infection from residual bacteria, toxins, or contaminants located in the internally threaded portion of the retained fractured implant. If the implant is in close proximity to a vital structure such as a neurovascular bundle or sinus cavity, it may be prudent to allow tissue to heal over, if fractured at a sufficiently low point, or to recontour the remnant to permit the tissue to cover it. If there are sufficient implants remaining to support the prosthesis, one or more fractured implants may be recontoured, albeit with great difficulty, and allowed to remain submerged. This is known as a sleeping implant (Fig. 5.4a, b). This avoids the surgery, time, cost, and additional pain associated with implant removal. However, the risks of leaving a fractured implant in the bone require the patient's informed consent and continual re-examination to monitor any potential problems. If the implant is vital for support of the remaining prosthesis and no other site can be used, a skilled surgeon should carefully remove the implant, followed by grafting and/or re-entry at a later time.

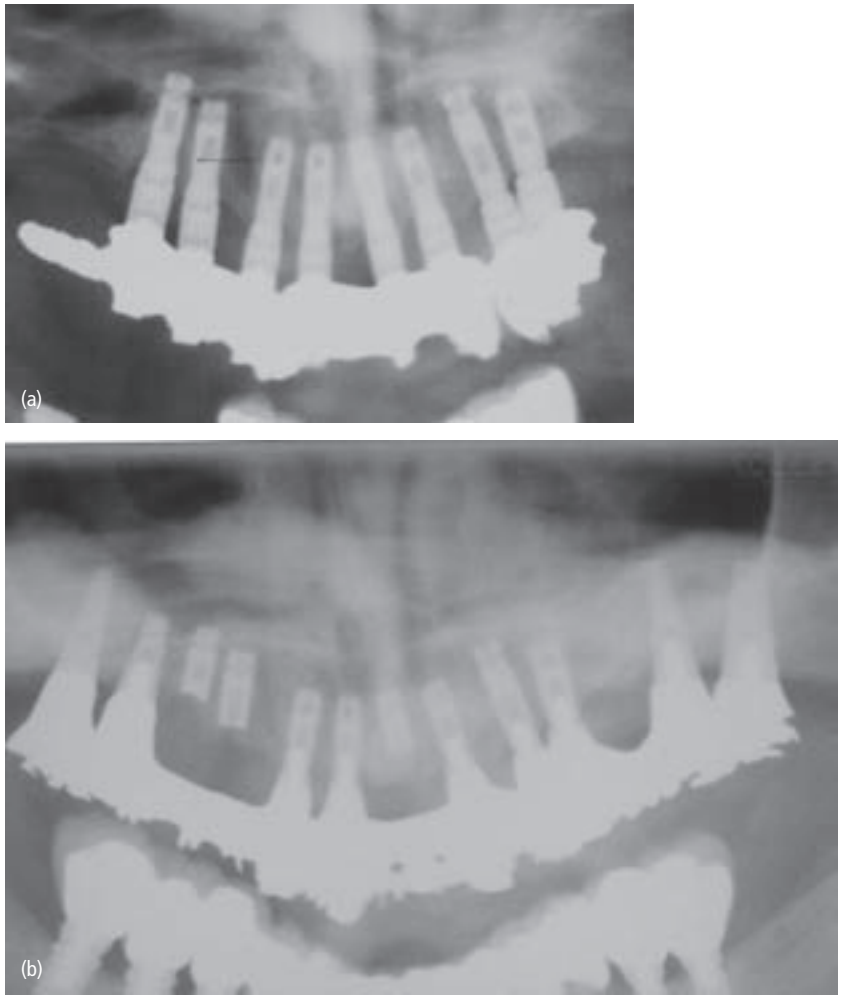


Fig. 5.4 (a) Maxillary fixed complete denture prosthesis with three implant fractures. The implant type is a 3.75 mm machined commercially pure titanium screw. (b) Salvaged case with four additional implants. (Courtesy of Stuart Froum.)

Conclusion

Little scientific research has been performed to assess implant fracture, with most information being derived from two long-term large population studies. Implant fracture results from a combination of factors:

- Most fractures documented in the scientific literature occurred in grade 1 titanium implants.
- Rate of fracture occurrence reduced dramatically following changes in screw design.
- Many fractures were observed following repeated screw loosening and bone resorption.
- The relationship between implant fracture and mechanical compromise of the implant platform has yet to be established.
- From the limited studies available, it appears that implant fractures occur more in partially dentate patients than in edentulous patients.
- In addition, many fractures occurred just below the engagement of the retention screw, where the "solid" implant becomes hollow, in an area where stress concentration occurs.

The above factors are dangerous in combination when the bone resorption level reaches the lower level of the retention screw.

Take-home hints

- When planning treatment in a partially edentulous patient, consider the length and diameter of the planned implants. Risk reduction may require more implants to engineer the prosthesis properly and prevent fracture.
- Occlusal guards are empirically recommended for all patients who exhibit parafunctional habits (bruxism, clenching, habitual gum chewing, and occupational habits).
- Whenever possible, avoid unsupported prosthetic extensions (cantilevers) in the molar areas.
- Be watchful for repeated screw-loosening scenarios and excessive bone loss.

References

1. Eckert SE, Meraw SJ, Cal E, Ow RK. Analysis of incidence and associated factors with fractured implants: a retrospective study. *Int J Oral Maxillofac Implants* 2000; **15**: 662–7.
2. Sutpideler M, Eckert SE, Zobitz M, An K-N. Finite element analysis of effect of prosthesis height, angle of force application, and implant offset on supporting bone. *Int J Oral Maxillofac Implants* 2004; **19**: 819–25.
3. Skalak R. Biomechanical considerations in osseointegrated prostheses. *J Prosthet Dent* 1983; **49**: 843–8.
4. Skalak R. Osseointegrated biomechanics. *J Oral Implantol* 1986; **12**: 350–6.
5. Skalak R. Stress transfer at the implant interface. *J Oral Implantol* 1988; **13**: 581–93.
6. Rangert B, Gunne J, Sullivan DY. Mechanical aspects of a Brånemark implant connected to a natural tooth: an *in vitro* study. *Int J Oral Maxillofac Implants* 1991; **6**: 177–86.
7. Rangert B, Jemt T, Jorneus L. Forces and moments on Brånemark implants. *Int J Oral Maxillofac Implants* 1989; **4**: 241–7.
8. Rangert B, Krogh PH, Langer B, Van Roekel N. Bending overload and impact fracture: a retrospective clinical analysis. *Int J Oral Maxillofac Implants* 1995; **10**: 326–34.
9. Balshi TJ. An analysis and management of fractured implants: a clinical report. *Int J Oral Maxillofac Implants* 1996; **11**: 660–6.
10. Adell R, Lekholm U, Rockler B, Brånemark PI. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. *Int J Oral Surg* 1981; **10**: 387–416.
11. Papazoglou EBW, McGlumphy EA. Characterization of retrieved implants: titanium, titanium alloys, and hydroxyapatite coatings. In: Eliades GET, Brantley W, Watts D, eds. *Dental materials in vivo; aging and related phenomena.* Chicago, IL: Quintessence, 2003: 52.
12. Kong L, Hu K, Li D, Song Y, Yang J, Wu Z, Liu B. Evaluation of the cylinder implant thread height and width: a 3-dimensional finite element analysis. *Int J Oral Maxillofac Implants* 2008; **23**: 65–74.
13. Craig R. *Craig's restorative dental materials*. St Louis, MO: Mosby-Elsevier, 2006.
14. Jaffin RA, Berman CL. The excessive loss of Brånemark fixtures in type IV bone: a 5-year analysis. *J Periodontol* 1991; **62**: 2–4.
15 Lin CL, Wang JC, Ramp LC, Liu PR. Biomechanical response of implant systems placed in the maxillary posterior region under various conditions of angulation, bone density, and loading. *Int J Oral Maxillofac Implants* 2008; **23**: 57–64.
16. Jemt T, Carlsson L, Boss A, Jorneus L. *In vivo* load measurements on osseointegrated implants supporting fixed or removable prostheses: a comparative pilot study. *Int J Oral Maxillofac Implants* 1991; **10**: 413–17.
17. Mericske-Stern R, Venetz E, Fahrländer F, Bürgin W. *In vivo* force measurements on maxillary implants supporting a fixed prosthesis or an overdenture: a pilot study. *J Prosthet Dent* 2000; **84**: 535–47.
18. Taylor TD, Wiens J, Carr A. Evidence-based considerations for removable prosthodontic and dental implant occlusion: a literature review. *J Prosthet Dent* 2005; **94**: 555–60.
19. Weinberg L. *Atlas of implant and tooth supported prosthodontics*. Chicago, IL: Quintessence, 2003.
20. Wiskott HW, Belser UC. A rationale for a simplified occlusal design in restorative dentistry: historical review and clinical guidelines. *J Prosthet Dent* 1995; **73**: 169–83.

Chapter 6

Implant failure: prevalence, risk factors, management, and prevention

Edwin S. Rosenberg BDSH Dip. Dent., DMD, FICD, FACD, *Cyril I. Evian* DMD, *J. Kobi Stern* DMD, MSc, *and Jonathan Waasdorp* DMD, MS

Introduction

Since the introduction of the concept of osseointegration by Brånemark and coworkers (1), dental implants have proven to be a predictable treatment option for the replacement of missing teeth (2, 3). The long-term survival rates of implants and implant-supported restorations have been demonstrated to be high, particularly with turned surface implants (2). Although roughened implant surfaces have been shown to integrate in shorter periods (6–8 weeks) and offer some clinical advantages over smooth surfaces, similar long-term data are not available on many of the implants currently being used.

As for short-term data, a recent meta-analysis that reviewed 51 studies, most of which were longitudinal cohort studies, reported on 5–10-year implant survival rates (4, 5). Patient-based data on implant losses were not retrievable in adequate numbers, so implant-based incidence rates were analyzed. Since most of the implant systems that were included in this review have been replaced by newer improved implant types and systems, implant survival rates today are most likely higher than those reported in the review (Fig. 6.1).

Currently, in spite of improved knowledge, technology, and experience, implant failure, even with its decreasing incident rates (6), is still considered by many clinicians a major risk in implant treatment.

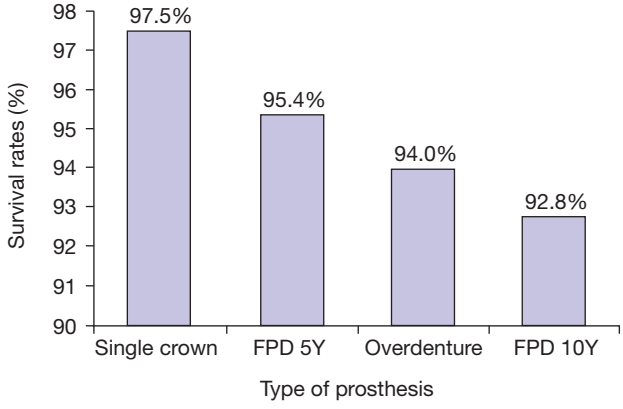


Fig. 6.1 Five- to ten-year implant survival rates. (FPD: fixed partial denture.)

Whatever technological and scientific improvements are made, implant therapy will always include a biological healing process and integration. The biological process is multifactorial and can be impaired by local, systemic, and operative factors that by acting either separately or in combination may lead to complications or implant failure.

The aim of this chapter is to discuss the prevalence, etiology and risk factors, prevention and management of implant failure. (The concept of implant esthetics failures will be discussed separately in Chapters 11 and 12.)

Definition and classification of implant failure

Definition of implant failure

For many years, an important limiting factor in comparing research on dental implant failure was the lack of different types of objective criteria used to define implant success and the changing parameters used to distinguish survival and success. Therefore, it is important to define the different terms used when dealing with implant failure:

- *Implant success.* Successful implants should fulfill a list of criteria considered essential for long-term survival. Traditionally, any implant that did not survive was deemed a failure. Criteria for implant success were defined by Albrektsson and Zarb (3) in 1986, followed and modified later by Roos *et al.* (7). Their success criteria serve as a gold standard for clinical and research purposes when new implants emerge (7–9). These criteria for success include: (i) no mobility; (ii) no radiographic evidence of peri-implant translucency; (iii) ≤1 mm bone loss 1 year following implant loading and ≤0.2 mm annually thereafter, absence of pain and pathology around the implant, and functional survival for 5 years in 90% and 10 years in 85%, of cases, respectively. Today the parameter of an esthetically acceptable implant has been added to the definition of implant success and conversely implant failure.

- *Implant survival*. While "surviving" implants may exhibit characteristics that may lead to eventual loss of the implant (e.g. severe osseous defects), such implants would not be considered successful (Fig. 6.2).
- *Implant failure*. This refers to the state where the implant has lost integration at a time-point following implant placement.
- *Failing implant*. This refers to an implant that is not mobile but has not fulfilled the predefined success criteria (Fig. 6.2). This entity, which specifically includes peri-implantitis, is discussed in Chapter 7.

Classification of implant failure

There are two commonly used periods to assess an implant failure that relate to the time of occurrence:

- *early failures*: failures before osseointegration, primarily the result of surgical and/or postoperative complications
- *late failures*: failures after the osseointegration period, usually arising during and after the restorative phase.

With either type of failure, there is no single etiological factor. Implant failures have been attributed to poor surgical technique, host factors that impair healing, poor bone quality, peri-implant infections, poor prosthesis design, and traumatic loading conditions. Early diagnosis of problems is critical and every effort should be made to treat the problem while the complication can still be managed or even reversed.

Historically, early failure usually occurred during the healing period within the range of the first year after an implant insertion. Today implant osseointegration can take place in a much shorter time (6–8 weeks) and is mainly defined clinically by clinical stability and radiographic evidence of peri-implant bone. At the time of the surgical placement of an implant, primary stability is achieved by mechanical means. Inability to achieve this during placement could be caused by improper surgical technique, poor systemic healing, or poor implant position. With advances in technology and treatment planning, implant placement including immediate loading or temporization of an implant or implants has become an established modality of treatment. This, however, has complicated the ability to differentiate between early and late failures, especially when the provisional prosthesis has been eliminated and multiple implants are loaded with the final prosthesis.

Incidence of implant failures

In spite of the impressive success rates of osseointegrated dental implants, there is a significant incidence of failures, according to several studies.

Rosenberg and Torosian (10) reported an overall failure rate of 7.0% in a 7.5-year investigation that aimed to identify clinical and/or microbiological differences associated with failure in five different implant systems.

Esposito *et al*. (11) present a meta-analysis of several studies, indicating that out of total implant failure 40% were early and 60% were late losses in the maxillae that had not been bone grafted. According to the same meta-analysis, half of the late failures were lost during their first year in function.

In a thorough analysis that included ten implant systems, Berglundh *et al*. (5) reported the incidence of implant loss in various prosthetic and surgical protocols before and during implant function.

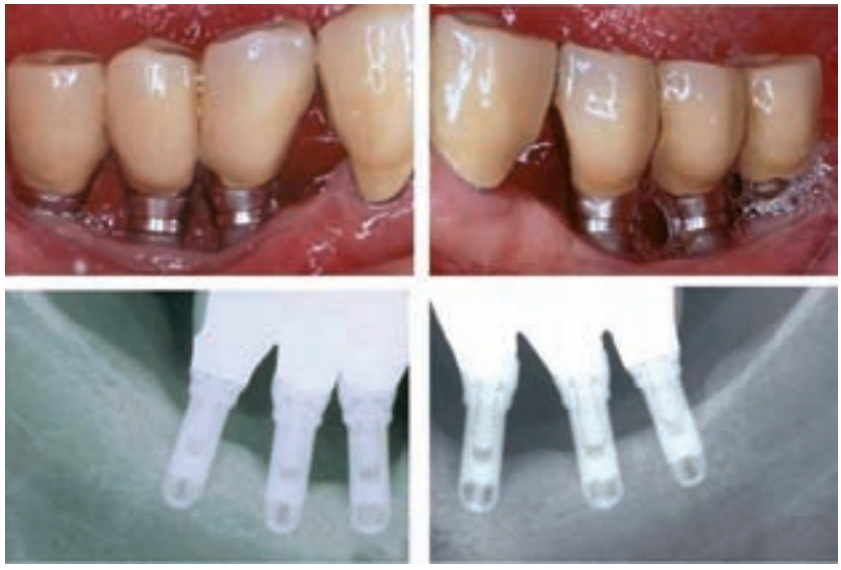


Fig. 6.2 Implants and restorations that are surviving but are not successful, according to the accepted criteria used for implant success. The implant at site no. 19 is in the process of failing.

From the authors' conclusions, although implant survival rates were high, implant loss and implant-related complications occurred in various situations.

Before functional loading, implant loss was reported to occur in about 2.5% of all implants placed in implant therapy, which included situations when more than one implant was placed and when routine procedures were used. Implant loss during function occurred in about 2–3% of implants supporting fixed reconstructions, while in overdenture therapy more than 5% of implants were lost during a 5-year period (5) (Fig. 6.3).

Etiology and risk factors

Implant failure can be caused by several factors, including.

- infection
- tissue trauma (e.g. overheating of bone, pressure necrosis)
- overload (e.g. transmucosal loading, occlusal trauma)
- iatrogenic.

It is unclear whether implants that are failing owing to an infective etiology had been affected by traumatic forces that led to the disintegration and spread of the inflammatory process around the implant.

Also, in a situation where an implant has failed at an early phase owing to tissue trauma leading to necrosis of the bone, it is not known whether the implant failed to integrate merely because of the necrosis of the tissue or because of an underlying infection. Therefore, there may be numerous situations where a combination of factors contributes to clinical implant failure.

For example, in the rare incident of implant fracture, infection and trauma often exist simultaneously, or subsequent to one another. Peri-implant bone loss due to infection (peri-implantitis) may also precede the implant fracture. Overload or trauma then becomes a secondary factor which causes the implant to fracture, at a certain level of the implant which is often concomitant with the

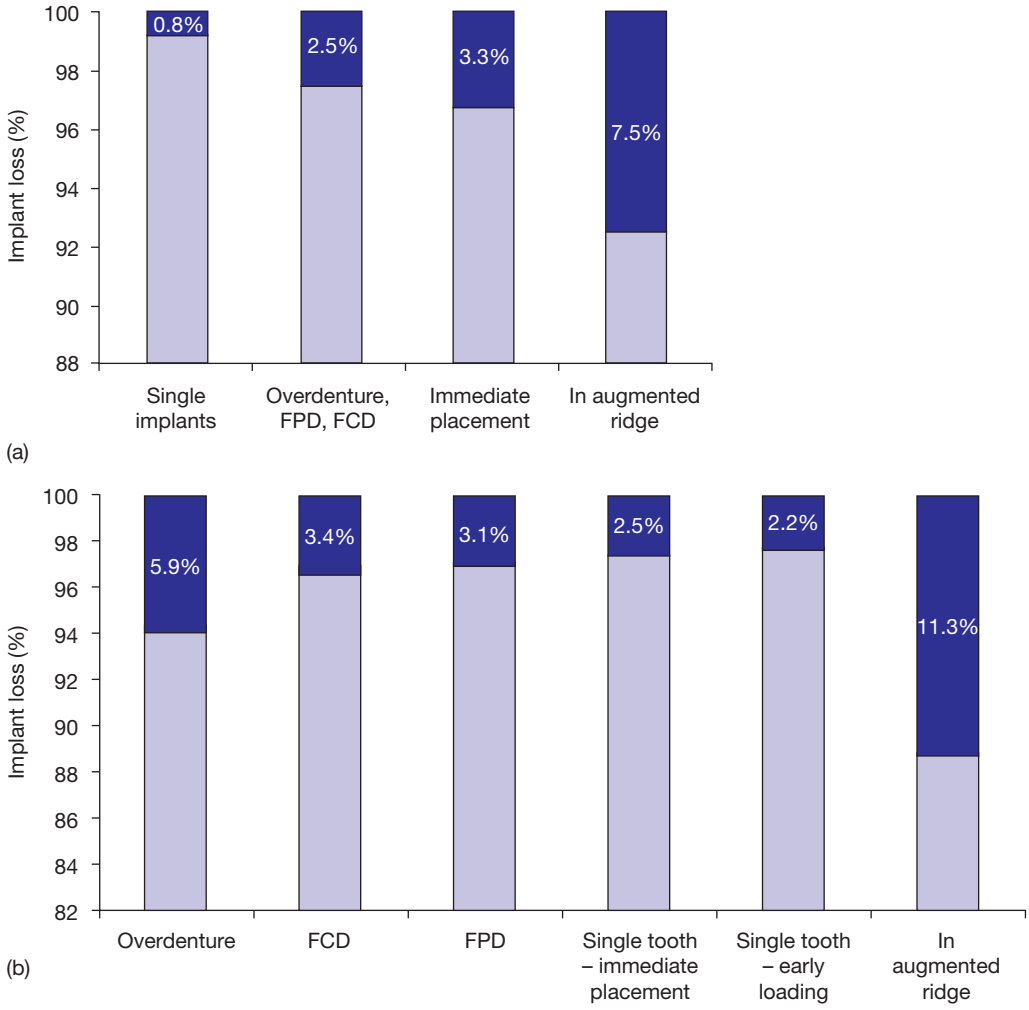


Fig. 6.3 Implant failure rates (a) before loading and (b) during 5 years of function, in different clinical scenarios and prosthetic solutions (4). (FCD: fixed complete denture.)

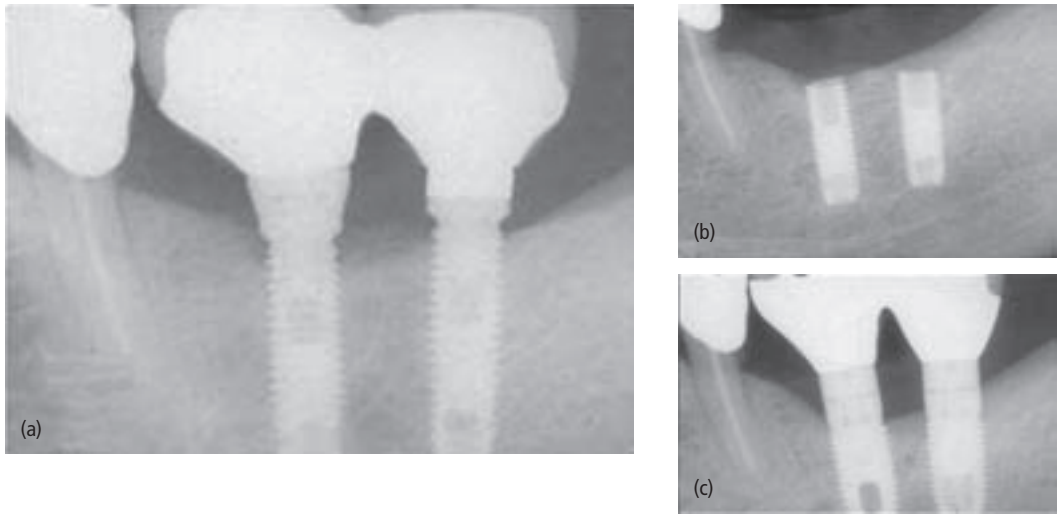


Fig. 6.4 (a) Implants no. 18 and 19 show evidence of marginal bone loss; (b) they finally fractured 2 years later. (c) After removal of the old implants, new implants were placed and restored.

level of bone-to-implant contact (Fig. 6.4a–c). This complication can occur in reverse order where the implant loses integration and fails owing to a superimposed peri-implant infection that acted on a site affected by occlusal trauma (Fig. 6.5a–c).

However, it has been shown that a distinct microbiota is associated with failure due to trauma compared with that which is associated with failures from infection.

Rosenberg *et al.* (12) showed that late fixture failure, resulting from infection, demonstrates a microbial flora resembling that of adult periodontitis, suggesting that peri-implant infections are site-specific infections similar to those that occur in adult periodontal disease. In contrast, implants failing as a result of trauma show an absence of motile rods, spirochetes, and classical periodontopathic organisms, and a predominance of Gram-positive organisms, similar to a healthy implant or periodontium (12).

Whether these same bacteria are associated with early implant failure due to infection is not known. From a microbiologic point of view, it remains unclear to what extent the organisms recovered are the cause of the failure or merely a result or manifestation of the infection. These two distinctive entities of implant failure can also be distinguished by the presence or absence of granulomatous tissue on the implants upon removal (12) (Fig. 6.6).

For a summary of the clinical characteristics of the two types of failure see Table 6.1.

Table 6.1 Parameters evaluated to determine the etiology of failure (12)

	Infectious	Traumatic
Pain	Yes	Yes/no
Mobility	Yes	Yes
Bleeding on probing	Yes	No
Suppuration	Yes	No
Increased probing depth	Yes	No
Gingival index	High	Low
Plaque index	High	Low
Attachment loss	Yes	No
Peri-implant radiolucency	Yes	Yes
Granulomatous tissue on removal	Yes	No

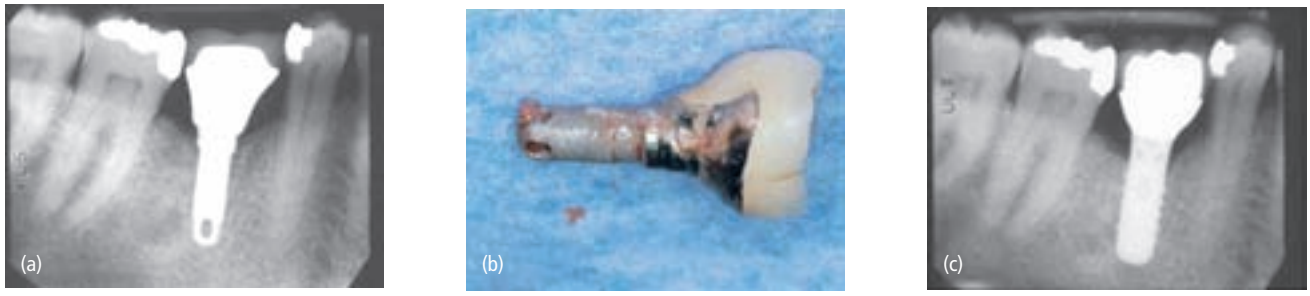


Fig. 6.5 (a) Occlusal overload due to incorrect occlusal anatomy that led to excess lateral forces. (b) Loss of integration with superimposed peri-implant infection. (c) Replaced implant with correct occlusal anatomy.

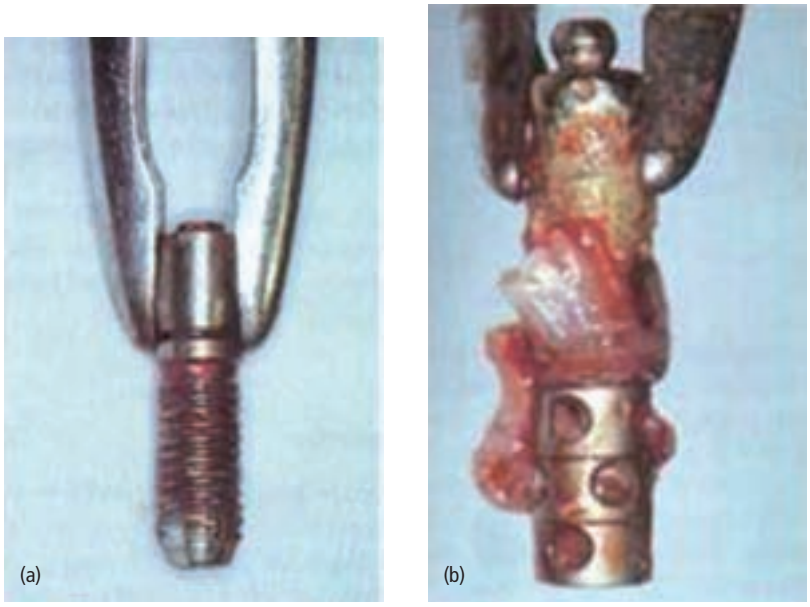


Fig. 6.6 Presence or absence of granulomatous tissue on retrieved implants that failed owing to (a) trauma or (b) infection.

Late implant failures due to peri-implantitis are covered in detail in Chapter 7.

Tissue trauma

An important factor in the etiopathogenesis of early implant failure is the overheating of the bone at surgical site. The critical temperature above which bone necrosis occurs is 47°C for 1 minute (13). Although other causes cannot be excluded, Piattelli *et al*. (14) have described the pathologic features of implant loss due to bone overheating. In all cases, it was accompanied by the same features: (i) presence of bone sequestra; (ii) no regeneration of the peri-implant bone; (iii) presence of an inflammatory infiltrate in the gap between bone and implant; (iv) no organization of the peri-implant bone clot; (v) presence of a compact and mature bone around the implant; and (vi) presence of bacteria and necrotic bone around the implant (14).

Iatrogenic factors

Implant therapy requires strict planning and execution. There are numerous sequential steps that have a significant impact on the final outcome. If all these events are not meticulously followed by the clinician, it could lead to increased failure and an increased complication rate.

Before the surgical stage there are appropriate and accurate imaging tools for accurate diagnosis and planning. If those are lacking, there is limited ability to diagnose bone morphology, existing pathology, and anatomic aberrations. This becomes especially important when dealing with a site in close proximity to significant vital anatomic landmarks (e.g. inferior alveolar nerve, morphology of a concave mandibular ridge, anterior mandible, and posterior maxilla). The resultant incorrectly placed implant would be considered a failure at the time of placement, i.e. an iatrogenic failure (Fig. 6.7).

Even in those situations where accurate imaging has been used, with computer axial tomographic (CAT) or cone beam computed tomography (CBCT) scans, if the surgical guide that is used is not correlated with the scan, improper implant positioning can result.

Iatrogenic failure may also include situations where surgical execution is associated with fracture of alveolar bony housing, sinus penetration, or any undue force leading to immediate loss of stability and which requires aborting the procedure.

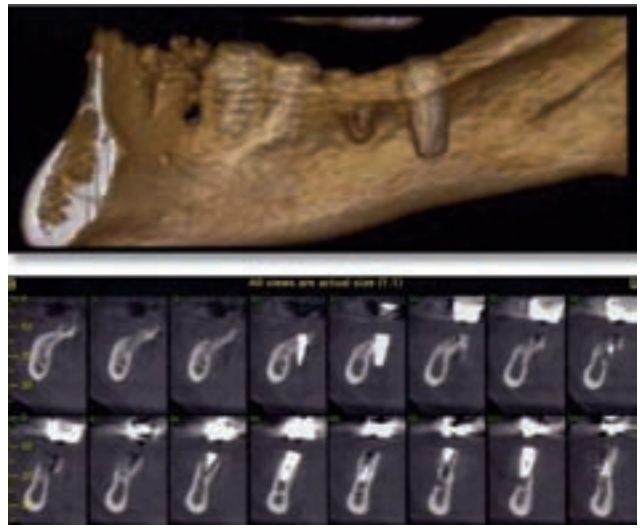


Fig. 6.7 Implant failure due to extra-alveolar position after the implant was placed by an inexperienced clinician without the use of a preliminary CT scan, which could have shown the severe anatomic concavity on the mandible.

The incorrect usage of surgical equipment such as blunt instruments, inadequate cooling protocols, and most importantly inadequate sterility of instruments and surgical site, may lead to an iatrogenic failure.

Many placement errors arise when dentists with inadequate training in diagnosis and treatment planning, evaluating systemic problems, and proper surgical skills for managing hard and soft tissues are faced with a complication.

The skill, knowledge, and expertise required for implant dentistry need time, practice, mentoring, and an accumulation of didactic information. Studies have shown that surgical experience with implant dentistry is related to survival at the second stage, especially for the first 50 implants placed (15). In a credentialed program the expected learning curve of the resident occurs through the 2–3-year length of the program and is controlled by the educational system and the experienced teachers in that program. In those situations where the practitioners avail themselves of programs that do not conform to those higher standards the learning curve is longer, and associated with higher failure rates.

Risk factors

Implant systems

Based on meta-analyses and randomized clinical trials that compared different implant systems and their clinical outcome, there is no evidence to show that any particular implant system has an increased risk for implant failure (16–19).

Eckert *et al*. (16) compared 5-year survival data from six implant manufacturers (Astra Tech, Centerpulse, Dentsply/Friadent, Implant Innovations, Nobel Biocare, and Straumann). A total of 59 articles was available for review, most of which were case series or expert opinion articles. Their observation demonstrated a significant similarity of all implant systems based on survival alone at 5 years. When all data were pooled, the 5-year survival rate of 96% (confidence interval 93% to 98%) was observed for a total of 7398 implants. Although the evidence was generally derived from case series rather than controlled clinical trials, the authors concluded that no obvious differences in implant survival were observed when comparing implant systems (16).

Concentrating on a higher level of evidence to compare different implant systems, Esposito *et al*. (19) reviewed 16 randomized clinical trials to compare 18 different implant types with a follow-up ranging from 1 to 5 years. Based on these studies, reporting results on a per-patient rather than a per-implant basis from a total of 771 patients, the authors concluded that no significant differences were observed between various implant types for implant failures (19).

The experience gained from studies investigating cluster phenomena of implant failure, where at least half of the inserted implants failed, indicates that certain important factors are associated with implant failure in these patients. These factors include poor bone quantity and quality, heavy smoking habits, and bruxism (20, 21).

In addition, although it has for many years been a controversial risk factor, there is accumulating evidence to suggest an increased risk for implant failure in patients who are susceptible to periodontitis (20, 22–27). Several systematic reviews that aimed to determine an association between a history of periodontitis and increased implant failure or complications have been published recently (28–31). All of these investigations conclude that patients treated for periodontitis may experience more implant loss and complications around implants than patients without periodontitis. Since survival rates of implant treatment in periodontitis-susceptible patients are still high, implant treatment is not contraindicated, as long as adequate infection control and an individualized maintenance program are provided. However, the higher incidence of peri-implantitis that is prevalent in these patients may jeopardize the longevity of the implant treatment (28–31).

Other host-related factors, such as a patient's general health, may play an important role in early implant failure, as reported in this study group. Examples of health risks include uncontrolled diabetes, osteoporosis, ongoing medication, and radiation therapy. Even though a review of the literature according to Esposito *et al*. (11) failed to prove a relation between implant losses and these factors, there seems to be a consensus that several factors play an important role in the mechanism of implant failure (see Chapter 2).

Treatment

The first step in treatment is to diagnose and identify the failed implant.

The clinical signs and symptoms of implant failure may include one or more of the following: mobility, edema, pain, pus, bleeding, and radiographic signs of peri-implant bone loss. These clinical signs may apply to both early and late failures. No distinction is made between early and late failures in terms of treatment.

In any case of implant failure where mobility is apparent, the implant should be removed immediately. Then the treatment sequence following depends on the site (anterior versus posterior) as well as the amount of tissue loss and the ability to provide primary stability for the replacement implant.

It is essential to diagnose a failing implant as early as possible to avoid further alveolar bone loss which might make the alternative of replacing the failed implant with

a new one more difficult and further compromise the esthetic outcome of the area.

The treatment options for managing implant failure include the following:

- immediate replacement of failed implant with a wider diameter implant
- simultaneous replacement of a failed implant with a guided bone regeneration procedure
- a staged approach where the lost tissue is first rebuilt, and the implant is then placed following site healing (delayed approach).

Since an underlying infection cannot be ruled out, antibiotic therapy accompanying any treatment is recommended.

The option of immediate replacement of failed implants with a wider diameter implant has been presented and discussed in the literature. Evian and Cutler (32) reported a case series of immediate replacement of failed screw-type, commercially pure titanium implants with larger diameter, hydroxyapatite-coated implants in the same sockets.

They suggest that invasive soft tissue can be eliminated with a larger diameter drill provided the socket can be prepared, the implant replacement is larger in diameter than the original implant, and sufficient available bone remains for the procedure. In their preliminary study all replacement implants became osseointegrated by second stage surgery 6 months after implant placement (32) (Figs 6.8a–c, 6.9).

The authors, however, recommend that immediate replacement should be considered very carefully, particularly in the esthetic zone. Placement of a wider implant in the esthetic zone can lead to resorption of the buccal cortical plate of bone, causing tissue recession and risking the final esthetic outcome. This applies particularly to the thin biotype tissue where additional trauma could result in much greater labial bone loss. However, in the posterior zone, where sufficient buccal bone remains it is possible to replace immediately the failed implant with a wider diameter implant. A healing period is recommended to allow for resolution of the underlying infection and soft-tissue healing.

Machtei *et al*. (33) recently investigated the survival rates of dental implants in previously failed implant sites. In their study 56 patients with a total of 79 redo implants were followed for 7–78 months (mean 29.9). Thirteen implants failed, which led to an overall survival rate of 83.5%. They concluded that redo dental implants have a lower survival rate than implants placed in pristine sites.

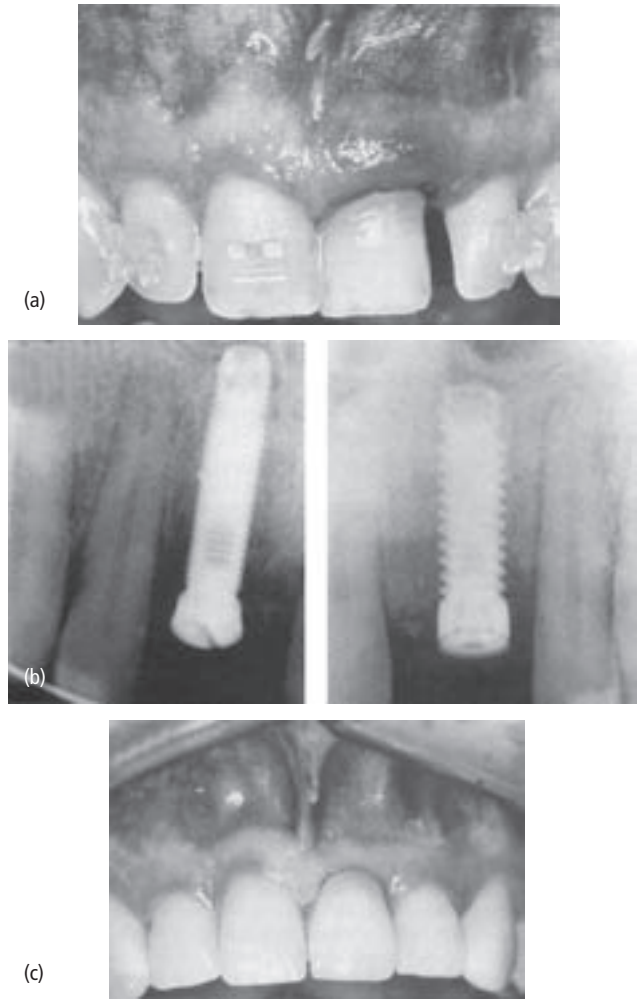


Fig. 6.8 (a) Maxillary left central incisor with labial swelling as a result of external root resorption. (b) Left: 18 mm Swede-Vent implant immediately placed after extraction of the central incisor, which failed after 6 weeks. Right: intact clinically osseointegrated wider diameter implant 6 months after replacement of the failed implant. (c) In the final restoration, a screw-retained crown is delivered.

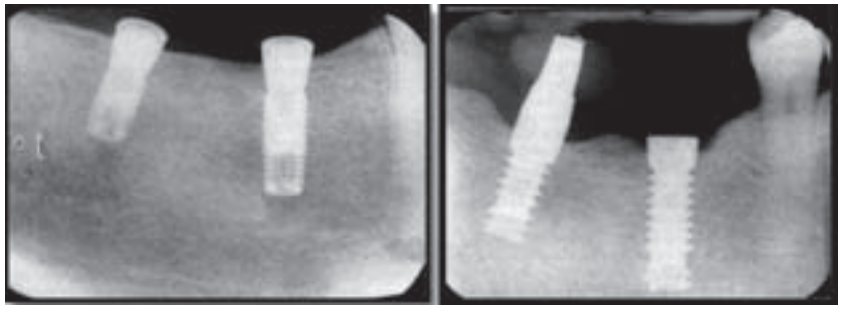


Fig. 6.9 Left: radiograph showing two conical self-tapping Swede-Vent implants which did not osseointegrate; right: wider diameter implants 6 months after immediate replacement of the failed Swede-Vent implants.

According to their findings, since most implant- and/or patient-related factors such as smoking habits, implant length and location did not have a significant effect on the outcome, a possible negative effect associated with the specific site of implant failure might account for this occurrence (33).

Clinical recommendations for prevention of implant failures

Fortunately, implant failure has become less common. However, for the patient and the clinician involved in an implant failure the complication is catastrophic. Many of these situations can often be avoided by meticulous planning and execution. Planning of the case using diagnostic radiographs, particularly CAT scan imaging, wax-ups, and attention to detail before and during implant procedures can minimize problems.

It has become evident that systemic and local risk factors such as diabetes, radiation therapy, smoking, poor oral hygiene, existing or historical periodontal disease, and type and amount of bone will significantly influence the outcome implant treatment. It is of utmost importance for the clinician to assess the risk-to-benefit ratio in each case, and plan the case such that the relevant risk factors are modulated before treatment.

In many situations where the patient's individual risk factors have not been brought under control, despite efforts to modulate them, implant failure and complications can be expected, and occasionally the cluster failure phenomenon occurs (20). Therefore, it is essential that the patient and clinician adhere to a prevention protocol that coincides with the systemic and local risk factors. If this protocol is not followed then implant treatment should be avoided, and other alternatives should be offered.

Finally, proper training should be achieved before advanced surgical or prosthodontic procedures are undertaken. If the individual clinician ascertains that a specific case or patient is beyond the scope of his or her ability, then the patient should be referred to the appropriate specialist.

Take-home hints

- Any sign of mobility at the postoperative visits after implant placement suggests a non-integrated implant. Do not attempt a "wait and see" approach; the sooner the implant is removed at this stage the better and faster the healing.
- In a failing implant due to infection, after removal of the implant the site must be degranulated and decontaminated before grafting.
- Adequate amounts of hard and soft tissue must be provided before implant placement to avoid most implant failures. Site development is essential when dealing with a lack of tissue, especially in the esthetic zone.
- Apically positioning the tissues to treat early peri-implantitis is a good therapeutic modality as it enables the patient to maintain the area more effectively.
- For intermediate or late failures it is better to remove the implant and if necessary bone graft onto the new surface rather than attempting grafts on the old contaminated surface. Primary closure is necessary.

References

1. Brånemark PI, Adell R, Breine U, Hansson BO, Lindström J, Ohlsson A. Intra-osseous anchorage of dental prostheses. I. Experimental studies. *Scand J Plast Reconstr Surg* 1969; **3**: 81–100.
2. Zarb GA, Schmitt A. The longitudinal clinical effectiveness of osseointegrated dental implants in anterior partially edentulous patients. *Int J Prosthodont* 1993; **6**: 180–8.
3. Albrektsson T, Zarb G, Worthington P, Eriksson A. The long-term efficacy of currently used dental implants: a review and proposed criteria of success. *Int J Oral Maxillofac Implants* 1986; **1**: 11–25.
4. Lang NP, Berglundh T, Heitz-Mayfield LJ, Pjetursson BE, Salvi GE, Sanz M. Consensus statements and recommended clinical procedures regarding implant survival and complications. *Int J Oral Maxillofac Implants* 2004; **19** (Suppl): 150–4.
5. Berglundh T, Persson L, Klinge B. A systematic review of the incidence of biological and technical complications in implant dentistry reported in prospective longitudinal studies of at least 5 years. *J Clin Periodontol* 2002; **29**: 197–212.
6. ADA Council on Scientific Affairs. Dental endosseous implants: an update. *J Am Dent Assoc* 2004; **135**: 92–7.
7. Roos J, Sennerby L, Leckholm U, Jemt T, Grodahl K, Albrektsson T. A qualitative and quantitative method for evaluating implant success: a 5-year retrospective analysis of the Brånemark implant. *Int J Oral Maxillofac Implants* 1997; **12**: 504–14.
8. Albrektsson T, Wennerberg A. Oral implant surfaces: Part 1 – Review focusing on topographic and chemical properties of different surfaces and *in vivo* responses to them. *Int J Prosthodont* 2004; **17**: 536–43.
9. Albrektsson T, Wennerberg A. Oral implant surfaces: Part 2 – Review focusing on clinical knowledge of different surfaces. *Int J Prosthodont* 2004; **17**: 544–64.
10. Rosenberg ES, Torosian J. An evaluation of differences and similarities observed in fixture failure of five distinct implant systems. *Pract Periodont Aesthet Dent* 1998; **10**: 687–98; quiz 700.

11. Esposito M, Hirsch JM, Leckholm U, Thomsen P. Biological factors contributing to failures of osseointegrated oral implants. (I). Success criteria and epidemiology. *Eur J Oral Sci* 1998; **106**: 527–51.
12. Rosenberg ES, Torosian JP, Slots J. Microbial differences in 2 clinically distinct types of failures of osseointegrated implants. *Clin Oral Implants Res* 1991; **2**: 135–44.
13. Eriksson RA, Adell R. Temperatures during drilling for the placement of implants using the osseointegration technique. *J Oral Maxillofac Surg* 1986; **44**: 4–7.
14. Piattelli A, Piattelli M, Mangano C, Scarano A. A histologic evaluation of eight cases of failed dental implants: is bone overheating the most probable cause? *Biomaterials* 1998; **19**: 683–90.
15. Lambert PM, Morris HF, Ochi S. Positive effect of surgical experience with implants on second-stage implant survival. *J Oral Maxillofac Surg* 1997; **55** (Suppl 5): 12–18.
16. Eckert SE, Choi YG, Sánchez AR, Koka S. Comparison of dental implant systems: quality of clinical evidence and prediction of 5-year survival. *Int J Oral Maxillofac Implants* 2005; **20**: 406–15.
17. Esposito M, Grusovin MG, Martinis E, Coulthard P, Worthington HV. Interventions for replacing missing teeth: 1- versus 2-stage implant placement. *Cochrane Database Syst Rev* 2007; (3): CD006698.
18. Esposito M, Grusovin MG, Coulthard P, Thompsen P, Worthington HV. A 5-year follow-up comparative analysis of the efficacy of various osseointegrated dental implant systems: a systematic review of randomized controlled clinical trials. *Int J Oral Maxillofac Implants* 2005; **20**: 557–68.
19. Esposito M, Murray-Curtis L, Grusovin MG, Coulthard P, Worthington HV. Interventions for replacing missing teeth: different types of dental implants. *Cochrane Database Syst Rev* 2007; (4): CD003815.
20. Jemt T, Hager P. Early complete failures of fixed implant-supported prostheses in the edentulous maxilla: a 3-year analysis of 17 consecutive cluster failure patients. *Clin Implant Dent Relat Res* 2006; **8**: 77–86.
21. Ekfeldt A, Christiansson U, Eriksson T, Lindén U, Lundqvist S, Rundcrantz T, *et al*. A retrospective analysis of factors associated with multiple implant failures in maxillae. *Clin Oral Implants Res* 2001; **12**: 462–7.
22. Baelum V, Ellegaard B. Implant survival in periodontally compromised patients. *J Periodontol* 2004; **75**: 1404–12.
23. Evian CI, Emling R, Rosenberg ES, Waasdorp JA, Halpern W, Shah S, Garcia M. Retrospective analysis of implant survival and the influence of periodontal disease and immediate placement on long-term results. *Int J Oral Maxillofac Implants* 2004; **19**: 393–8.
24. Rosenberg ES, Cho SC, Elian N, Jalbout ZN, Froum S, Evian CI. A comparison of characteristics of implant failure and survival in periodontally compromised and periodontally healthy patients: a clinical report. *Int J Oral Maxillofac Implants* 2004; **19**: 873–9.
25. Brocard D, Barthet P, Bayse E, Duffert JF, Eller P, Justumus P, *et al*. A multicenter report on 1,022 consecutively placed ITI implants: a 7-year longitudinal study. *Int J Oral Maxillofac Implants* 2000; **15**: 691–700.
26. Karoussis IK, Muller S, Salvi GE, Heitz-Mayfield LJ, Brägger U, Lang NP. Association between periodontal and peri-implant conditions: a 10-year prospective study. *Clin Oral Implants Res* 2004; **15**: 1–7.
27. Hardt CR, Grondahl K, Lekholm U, Wennström JL. Outcome of implant therapy in relation to experienced loss of periodontal bone support: a retrospective 5-year study. *Clin Oral Implants Res* 2002; **13**: 488–94.
28. Karoussis IK, Kotsovilis S, Fourmousis I. A comprehensive and critical review of dental implant prognosis in periodontally compromised partially edentulous patients. *Clin Oral Implants Res* 2007; **18**: 669–79.
29. Ong CT, Ivanovski S, Needleman IG, Retzepi M, Moles DR, Tonetti MS, Donos N. Systematic review of implant outcomes in treated periodontitis subjects. *J Clin Periodontol* 2008; **35**: 438–62.
30. Schou S. Implant treatment in periodontitis-susceptible patients: a systematic review. *J Oral Rehabil* 2008; **35** (Suppl 1): 9–22.
31. Van der Weijden GA, van Bemmel KM, Renvert S. Implant therapy in partially edentulous, periodontally compromised patients: a review. *J Clin Periodontol* 2005; **32**: 506–11.
32. Evian CI, Cutler SA. Direct replacement of failed CP titanium implants with larger-diameter, HA-coated Ti-6Al-4V implants: report of five cases. *Int J Oral Maxillofac Implants* 1995; **10**: 736–43.
33. Machtei EE, Mahler D, Oettinger-Barak O, Zuabi O, Horwitz J. Dental implants placed in previously failed sites: survival rate and factors affecting the outcome. *Clin Oral Implants Res* 2008; **19**: 259–64.

Chapter 7

Peri-implantitis: etiology, pathogenesis, prevention, and therapy

Niklaus P. Lang DMD, MS, PhD, Odont. dr. h.c. mult., Hon. FRCPS *and*
Maurizio S. Tonetti DMD, MSSc, PhD

Etiology: microbiologic aspects

Biofilm formation

Oral implants represent hard, non-shedding surfaces in a fluid system, as do teeth (1). As such, they are subjected to biofilm formation. A layer of glycoproteins will coat the implant surfaces that are exposed to the oral environment. Already after a few minutes to hours after implant installation, single bacterial colonies will adhere to the pellicle coat (Fig. 7.1). Following this, the colonies will divide and form larger and more expansive aggregates of oral bacteria. Such early colonization is usually predominated by a Gram-positive coccoidal and rod microbiota. As time passes, the biofilm development will result in a more complex microbiota, the composition of which is dependent on the microbiota of the entire oral ecosystem (Fig. 7.2).

Development of the peri-implant microbiota

Natural colonization in edentulous patients

The development of the microbiota in the peri-implant sulcus was first studied in edentulous patients using anaerobic culturing techniques (2). It was evident that the colonization process of the peri-implant sulcus in an edentulous patient originated from the microbiota floating in saliva and was not affected by the microbiota residing in already existing gingival sulci or periodontal pockets. Mucosal swab samples were obtained from edentulous ridges before the installation of one-stage transmucosal implants. Subsequently, sterile paper point samples were retrieved at weekly intervals for the first 2 months and then at monthly intervals for the next 4 months. Already after 2 weeks, a microbiota in the peri-implant sulcus was established which was predominated by Gram-positive facultative bacteria closely resembling the microbiota associated with gingival health or gingivitis (2). In one peri-implant sulcus of a patient with a history of a previous peri-implant infection which led to the loss of that implant, however, high proportions of Gram-negative anaerobic bacteria and spirochetes were detected after 120 days. Clinically, this microbiota was associated with heavy signs of inflammation and early signs of infection, leading to antimicrobial treatment in this patient (2).

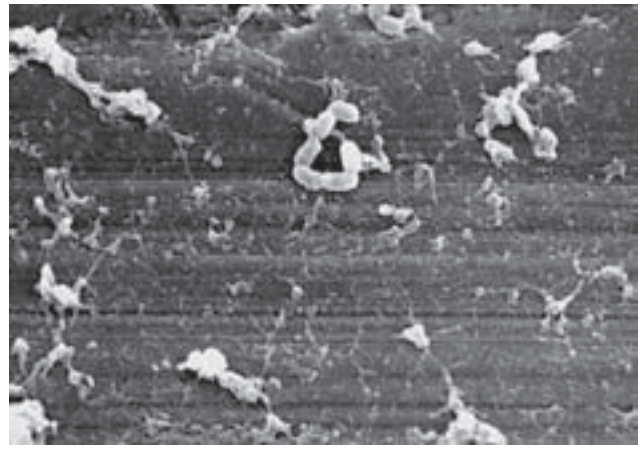


Fig. 7.1 Scanning electron micrograph depicting an implant surface 2 hours after installation. Strands of pellicle forming on the hard, non-shedding surface with early colonization of single bacterial colonies (coccoid cells). (Courtesy of Dr S. Abati.)

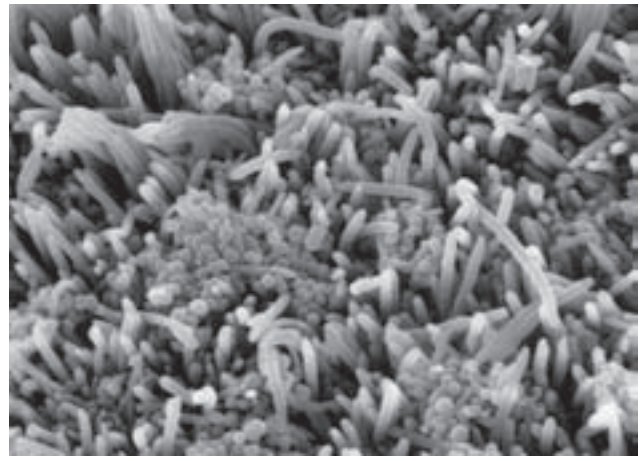


Fig. 7.2 Scanning electron micrograph depicting an implant surface 7 days after implant installation. A mature biofilm has established with colonization of a filamentous and rod-dominated microbiota. (Courtesy of Dr S. Abati.)

Colonization in partially edentulous patients

Prospective studies on the colonization of peri-implant sulci in partially edentulous patients are sparse. Obviously, residual periodontal pockets harboring high proportions of presumptive periodontal pathogens may influence the colonization of the peri-implant sulcus. Three and six months after installation of one-stage transmucosal implants in one practice and after abutment connection of two-stage submerged implants in another, it was demonstrated that the same bacteria found in residual periodontal pockets at the time of implant installation also colonized the peri-implant sulcus (3). If periodontal pathogens were identified in pockets they were also detected at implant sites 3 months later. This, in turn, means that during the development of the biofilm the colonization pattern may substantially be influenced by bacterial colonization from various niches within the oral environment (4). Thus, untreated periodontitis may represent a risk for the establishment of a pathogenic microbiota in the peri-implant sulcus.

Recently, early bacterial colonization has been studied using checkerboard DNA–DNA hybridization techniques before, 30 minutes after implant installation, and 1–12 weeks after surgery (5). The colonization of the peri-implant sulcus occurred within 30 minutes. Moreover, colonization patterns differed between implant and tooth surfaces. This is consistent with the results from a number of studies establishing that colonization of subimplant surfaces may occur within 10–14 days after insertion surgery (6, 7).

Microbiota associated with peri-implant infections

Association studies have identified the microbiota in the peri-implant sulcus or pocket with either adjacent healthy or inflamed mucosal tissues. Initially, bacterial morphotypes were identified using electron (8) and dark-field microscopy (9). Later on, anaerobic bacterial culturing techniques were applied to study the association of the microbiota with different peri-implant conditions (10–13). Basically, the microbiota associated with healthy peri-implant tissues or mucositis closely resembled the microbiota associated with gingival health or gingivitis, respectively. In contrast, the microbiota identified in peri-implant infections was in many, but not all cases, identical to that encountered in pockets with advanced periodontitis (14) (Fig. 7.3). Differences may exist in how microorganisms colonize on a tooth compared with a titanium implant surface. Thus, *Staphylococcus aureus*, a pathogen commonly not considered in periodontal microbiologic research (15), is known to have an important ability to attach to almost any biofilm on titanium (16). It is established that a significant proportion of medical implants become the focus of a device-related infection. Such infections are difficult to eradicate because bacteria that cause these infections live in well-developed and protective biofilms. *Staphylococcus aureus* autolysin may be an important factor in the early colonization of such implant devices, including oral titanium implants.

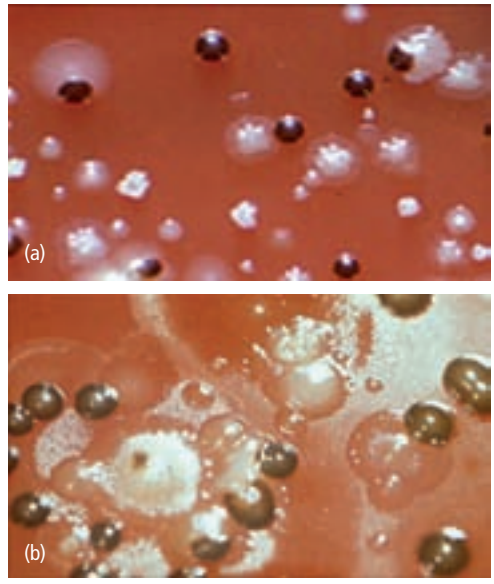


Fig. 7.3 Blood agar plates yielding a predominantly Gram-negative anaerobic microbiota with numerous black pigmenting microorganisms (*Porphyromonas gingivalis*, *Prevotella intermedia*). (a) Sample retrieved from a 7 mm periodontal pocket (periodontitis). (b) Sample retrieved from a 7 mm peri-implant pocket (peri-implantitis).

Pathogenesis of peri-implant diseases

At the First European Workshop on Periodontology in 1993, two disease patterns associated with oral implants were identified and defined. *Peri-implant mucositis* is a term used to describe reversible inflammatory reactions in the mucosa adjacent to an implant (Fig. 7.4). *Peri-implantitis* is defined as an inflammatory process that (i) affects the tissues around an osseointegrated implant in function and (ii) results in loss of supporting bone (Fig. 7.5).

Peri-implant mucositis

Animal models

De novo biofilm formation and its host response have been studied histologically in a beagle dog model (17). It was found that the inflammatory infiltrate developing as a result of the bacterial challenge was equal in size regardless of whether it was adjacent to control teeth or to oral implants, indicating that the host response to bacterial colonization triggered in gingiva is equal to that of peri-implant mucosa.

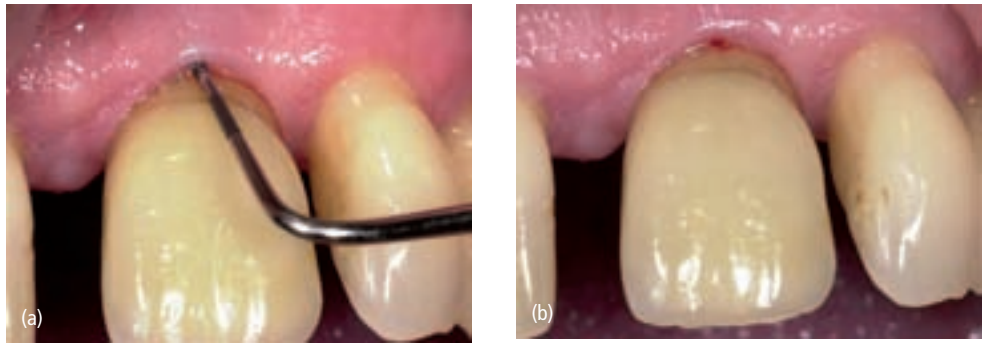


Fig. 7.4 (a) Probing of a peri-implant sulcus applying light force (up to 0.25 N). (b) Bleeding on probing indicating peri-implant mucositis.

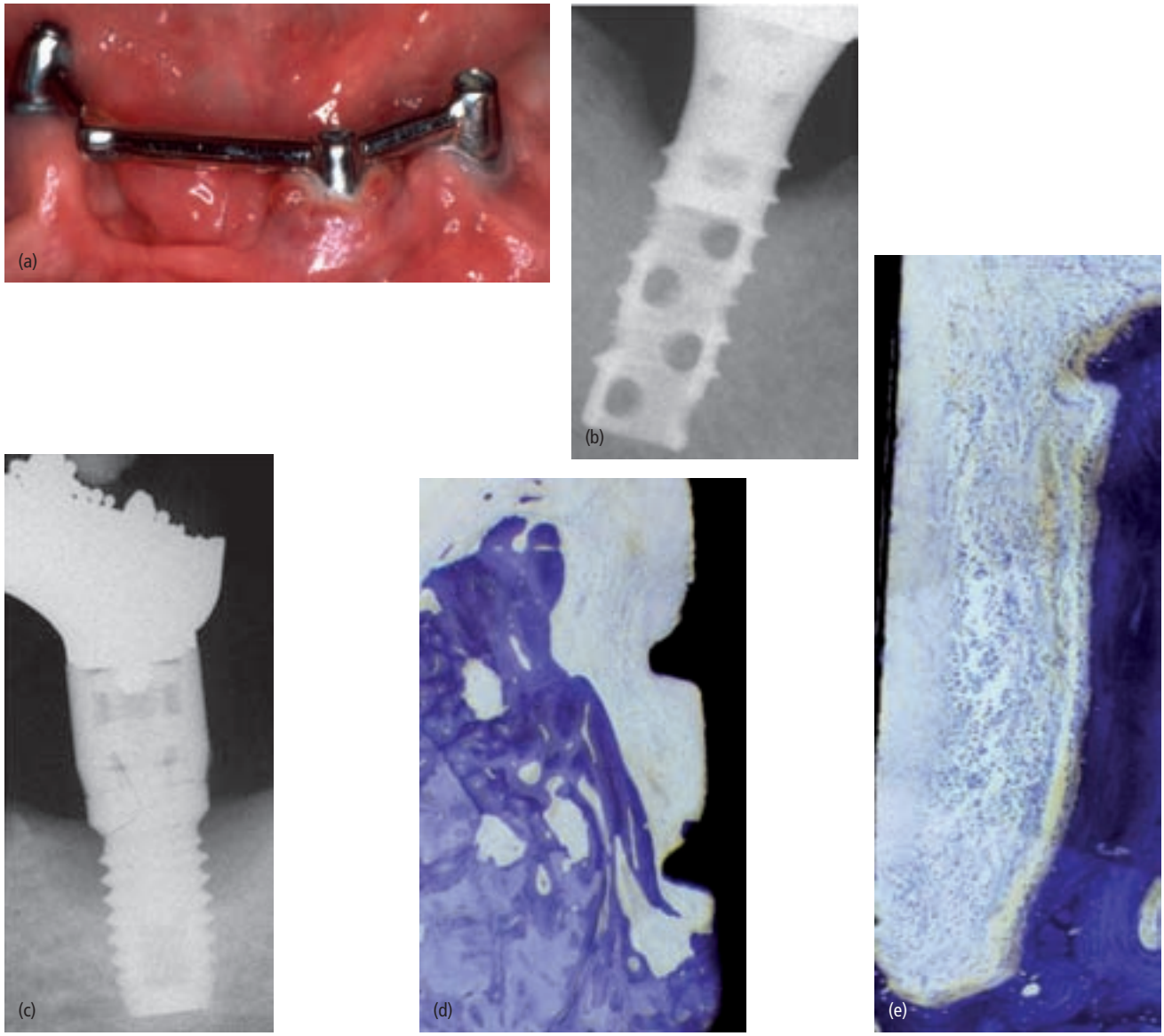


Fig. 7.5 Peri-implantitis. (a) Clinical appearance of an implant with peri-implantitis in an edentulous mandible in the region of the lower left canine in comparison to implants characterized by healthy or mucositis-affected peri-implant tissues in the region of the mandibular second premolars. (b) Radiographic documentation of peri-implantitis characterized by a saucer-shaped circumferential bony defect. (c) Advanced peri-implantitis lesion. (d) Histologic documentation of the lesion identified in (c). The lesion is fully occupied with biofilm and bone resorption is distant to the implant surface; bone remodeling is also visible, indicating a dynamic process. (e) Higher magnification of the lesion showing biofilm on the implant surface. (c, d, e: Courtesy of Prof. T. Berglundh.)

Human studies

Local defense mechanisms of the peri-implant soft-tissue seal were studied and compared with those of the dentogingival unit. The production of inflammatory mediators and the expression of cytokines appeared to be very similar in these two soft-tissue compartments (18). Also, the experimental gingivitis model originally described by Löe *et al*. (19) and representing the ultimate proof for a cause-and-effect relationship between biofilm formation and developing gingivitis was duplicated with regard to the peri-implant situation (20). After a period of 6 months with meticulous plaque control after abutment connection of a two-stage submerged implant system, patients were asked to discontinue all oral hygiene practices for a period of 3 weeks. At the end of the 3-week period, there were no significant differences between any of the clinical parameters assessed at gingival control and peri-implant mucosal sites (Fig. 7.6). Both soft-tissue compartments yielded increased gingival indices and increased probing depths as a result of increased plaque accumulation and hence, the cause-and-effect relationship between bacterial plaque and the developing mucositis was also convincingly established for oral implants (20).

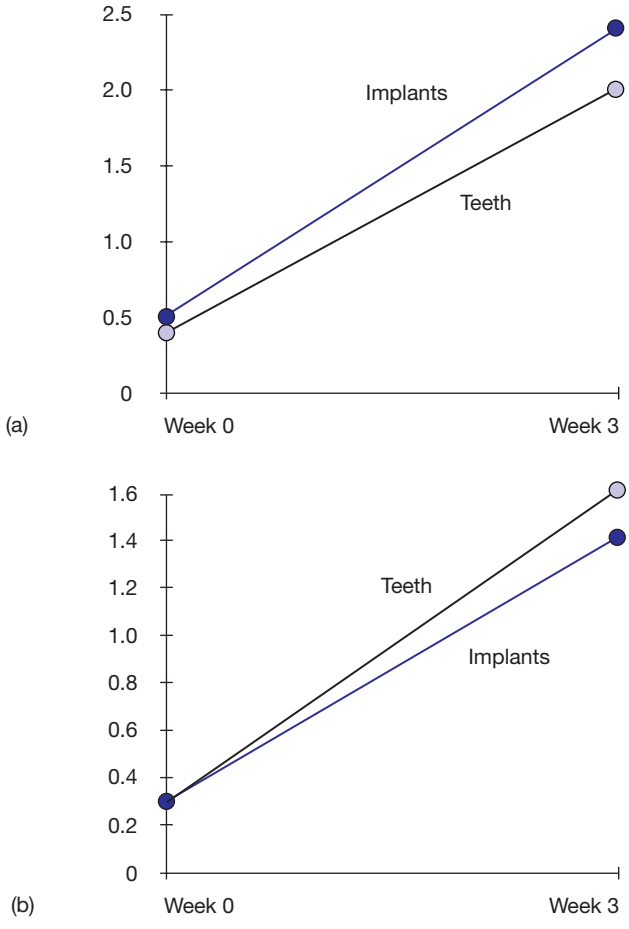


Fig. 7.6 Experimental peri-implant mucositis in men. Clinical parameters assessed during a 3-week period of no oral hygiene resulting in the development of gingivitis and mucositis. Establishment of a cause-and-effect relationship between the biofilm development and the host response. (a) PII: plaque index (20). (b) SBI: sulcus bleeding index (21). (Adapted from Pontoriero *et al*. (20).)

Peri-implantitis

For ethical reasons, experimental studies of peri-implant infections cannot be conducted in humans. Hence, the information gathered in this field must rely on animal studies. Unfortunately, the results in previous peri-implantitis studies have been somewhat conflicting as to the rate and extent of progression of peri-implantitis lesions. While a pilot study (23) proposed a slower progression rate of disease at the implant site in comparison with the natural tooth, a series of beagle dog studies (24) cautioned that peri-implant lesions may develop directly into the alveolar bone, whereas periodontitis lesions always seem to yield a supracrestal region with intact periodontal fibers.

Other groups of researchers (25, 26) induced peri-implantitis and periodontitis in control teeth by applying plaque-accumulating ligatures and compared the disease process with that induced by natural plaque accumulation in a monkey model. The increase in the clinical parameters such as plaque and gingival indices as well as pocket depth and loss of attachment around teeth exactly paralleled that of the ligated peri-implantitis sites. After 8 months of ligation, approximately 3.5 mm of attachment was lost, while the implants that were only exposed to natural plaque accumulation lost no more than 0.5 mm over the same period. The microbiota identified around the ligated teeth also corresponded to that surrounding the ligated implants. In addition, the lesions analyzed histologically after 8 months were very similar and represented intrabony defects (Fig. 7.5). Digital subtraction radiography (DSR) showed a loss of bone density and identified the development of intrabony lesions around ligated teeth as well as around ligated implants, while the bone height and density did not significantly change around the implants with natural plaque accumulation during the experimental period. This, in turn, means that – under heavy plaque accumulation and in a period long enough for the development of infections – lesions may progress into the supporting tissues around implants as they do around teeth. Peri-implantitis, however, may not develop in all peri-implant sites with mucositis, just as periodontitis may not develop in all sites with gingivitis.

The histopathologic examination of biopsy samples from a dog study (24) revealed marked differences in the size and location of the inflammatory lesions of periodontal and implant sites. Thus, while the lesions in the periodontal sites consistently were separated from the

alveolar bone by a zone of non-inflamed connective tissue, the lesions in the peri-implant tissue in most situations extended into and involved the marrow spaces of the alveolar bone.

It was concluded that the pattern of spread of inflammation was different in periodontal and peri-implant tissues. The lesions in plaque-associated periodontitis were limited to the connective tissue, while in the peri-implant tissues the lesions also involved the alveolar bone. In contrast to the periodontal tissues, the peri-implant tissues appeared to be poorly encapsulated to resolve progressive, plaque-associated lesions and extend into the marginal bone tissue and may, if they are allowed to progress, lead to the loss of the implant. Further studies (27–30) using dog models, but allowing for different periods of tissue breakdown, have confirmed this conclusion.

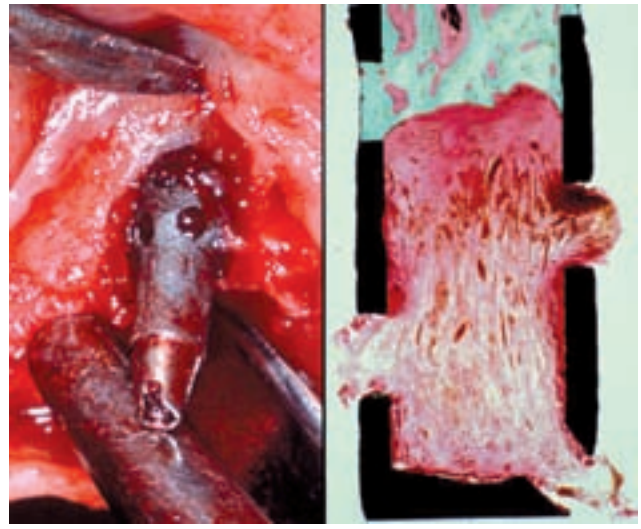


Fig. 7.7 Mobility: a parameter of very poor sensitivity and high specificity. (a) Hollow cylinder implant with peri-implantitis. The lesion has reached the inner compartment of the implant body, leading to explantation. (b) Histologic documentation of the explanted implant from (a). The lesion is very well delineated, and osseointegration in the apical portion of the implant is still present. Consequently, the implant remains stable despite advanced peri-implantitis.

Diagnostic aspects

Mobility

Since peri-implant infections represent lesions originating from the marginal peri-implant sulcus (24–26), the bone loss encountered in association with the development of such infection is also observed to be marginal and results in the formation of intrabony defects around the implant and a saucer-shaped configuration of the lesion. This, in turn, means that the implant still remains fully osseointegrated in the apical portion, and hence, an increase in implant mobility cannot be expected. In contrast, loss of clinical stability as a result of complete loss of osseointegration would be reflected in a sudden increase in implant mobility (Fig. 7.7). Therefore, an increase in clinical mobility represents a highly specific, but not at all sensitive, parameter for monitoring clinical stability. Assessment of implant mobility in routine evaluations and clinical monitoring of implants is, therefore, not essential, but when used must always be performed in conjunction with the evaluation of other parameters.

Bleeding on probing

Bleeding on probing (BOP) represents a clinical parameter which is defined as the presence of bleeding noticed after the penetration of a periodontal probe into the peri-implant sulcus or pocket using gentle force (31). The size (point diameter) of the probe applied and the application force should be standardized. For teeth, the probing pressure for this parameter has been determined. In the healthy and normal periodontium, the probing force used is 0.25 N (32). The same force is used in a healthy but periodontally reduced dentition (33). Recently, the application of the same probing force for the determination of BOP around oral implants has been established (31). Hence, standardized probes which produce standardized probing forces may be recommended.

BOP has been studied for its value in predicting future attachment loss around teeth (34). While the positive predictive value remained rather low for repeated BOP prevalence in one retrospective (34) and two prospective (35, 36) studies (30% or less), the negative predictive value in the same studies reached almost 100%. This shows that the absence of BOP is a very reliable indicator for periodontal stability (35). Similar data for oral implants have been gathered in a prospective cohort study (37). The diagnostic accuracy of BOP was significantly higher than that of teeth. Hence, from a clinical point of view, absence of BOP around implants would indicate healthy peri-implant tissues (Fig. 7.8).

Modified gingival index

The gingival index (GI) system (21, 38) has been modified and adapted by Mombelli *et al.* (11) for application around oral implants. Although the modified GI may be used to assess the status of health or inflammation in peri-implant mucosal tissues, and hence to indicate mucositis in clinical research, it may be preferable and simpler to use BOP for routine clinical documentation. Calibration exercises to determine the accuracy and repeatability of examiners using BOP should be performed before initiating studies in the same manner as for the GI.

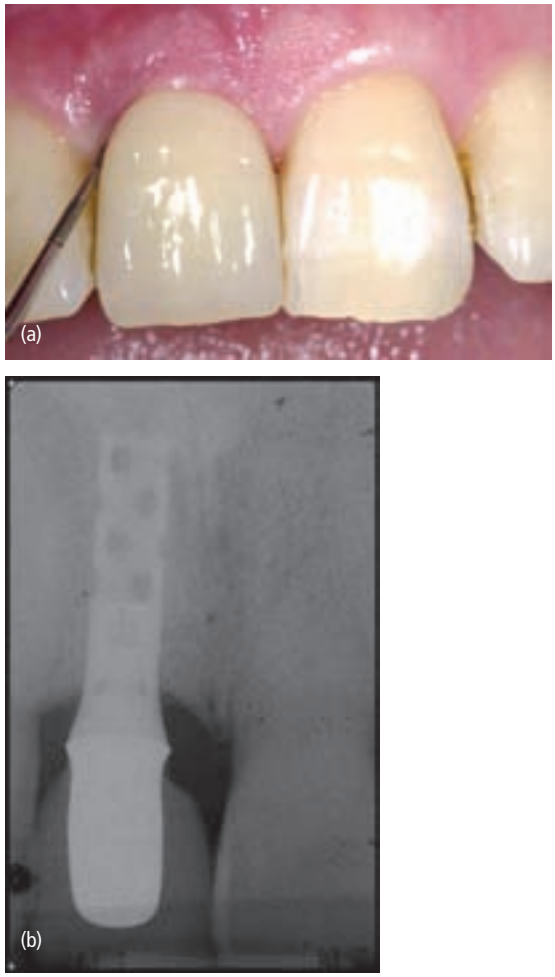


Fig. 7.8 Bleeding on probing (34, 37). (a) Absence of bleeding on probing on light force application indicates peri-implant stability. (b) Radiograph confirming absence of any peri-implant bone loss after 5 years of function.

Probing depth and loss of attachment

Periodontal probing to determine probing depth and the level of periodontal attachment in relation to the cementoenamel junction (CEJ) is the most widely used clinical parameter in periodontal practice. Again, it appears logical to apply these parameters to the peri-implant mucosal seal. Instead of relating probing depth to the CEJ, clinicians may use the implant shoulder, which provides a landmark that is easy to localize in clinical practice.

Although opinions have been expressed that peri-implant probing may sever the soft-tissue seal and hence jeopardize the integrity of an implant, there is no scientific evidence for such concern. On the contrary, it may be assumed that after probing the peri-implant epithelial attachment to the titanium surface may be re-established within the course of 4–5 days (39) (Fig. 7.9), as already established for teeth (40).

Christensen *et al*. (41) found that clinical probing depth determined by three automatic probing devices yielded slightly higher values around oral implants (approximately 0.5 mm higher) than around healthy contralateral control teeth. Also, the buccal and lingual aspects of oral implants generally scored 0.5–1.0 mm less than the interproximal aspects. Probing depth around oral implants may be system specific and dependent on access of the probe to the peri-implant sulcular region. Hence, different probing depth values may be considered as "normal" in different implant systems. As an example, for the Straumann® dental implant system, normality associated with healthy peri-implant mucosal tissues averaged 3–3.5 mm (41).

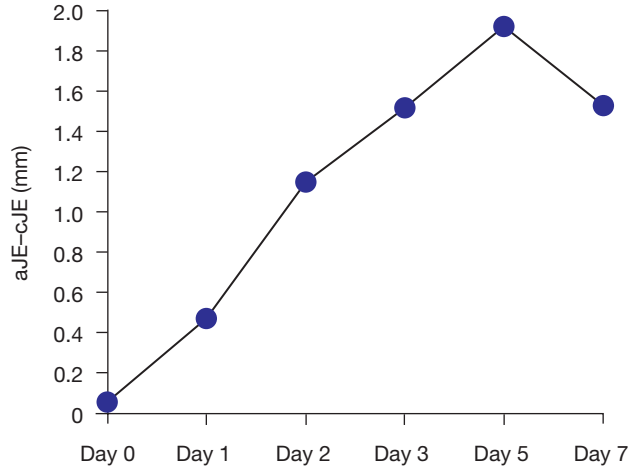


Fig. 7.9 Healing of the epithelial attachment following probing of the peri-implant sulcus. Distance from the most apical cell of the junctional epithelium (aJE) to the most coronal cell of the junctional epithelium (cJE) increases linearly up to 5 days indicating complete healing of the epithelial attachment following probing. (Adapted from Etter *et al*. (39).)

The localization of the periodontal probe tip around implants has been studied in different mucosal tissue conditions such as health, mucositis, and peri-implantitis (42). While the probe tip reached and identified the true level of attachment, i.e. the most apical cell of the junctional epithelium, within 0.2 mm in health and mucositis, the histologic level of attachment was generally determined to be up to 1.2 mm more coronal than measured by clinical probing in peri-implantitis sites (Fig. 7.10) (42). These results confirm the excellent sealing effect of the soft-tissue collar in health and mucositis and the relatively uninhibited penetration to the alveolar crest of the probe in peri-implantitis lesions. In another animal study (43), in which higher probing forces were used, the probe tip penetration usually went through the epithelial attachment until resistance was met as a result of reaching the alveolar crest.

Since the soft-tissue seal inhibited probe tip penetration in healthy and only slightly inflamed peri-implant soft tissues, but did not do so in peri-implantitis, probing around oral implants must be considered a sensitive and reliable clinical parameter for long-term clinical monitoring of peri-implant mucosal tissues.

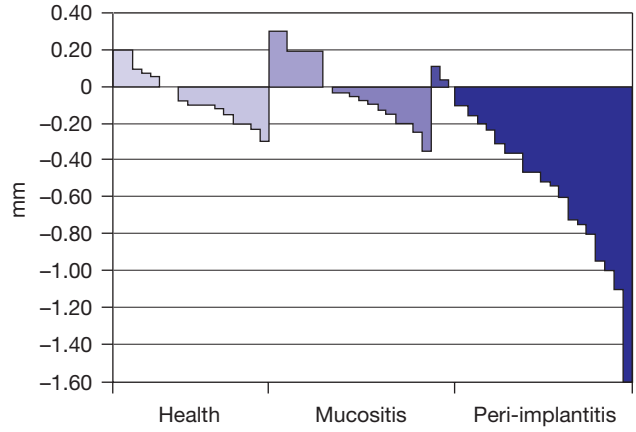


Fig. 7.10 Probing errors in relation to the tissue characteristics around implants. The histologic attachment level (HAL) and the histologic probing depth (HPD) at 0.2 N probing force differ up to 0.2 mm in peri-implant health and mucositis, while the difference between the two positions is up to 1.2 mm in peri-implantitis sites. This means that probing is a highly sensitive parameter for the diagnosis of peri-implantitis. (Adapted from Lang *et al.* (42).)

In view of the fact that implants may be positioned more apically in areas of esthetic priority to reach optimal emergence profiles for the reconstruction, it is of utmost importance to establish "normal" baseline probing depths around implants after the incorporation of the prosthetic reconstruction. Repeated subsequent comparisons of probing depth and loss of implant support (loss of attachment) in comparison with baseline measurements are highly recommended.

Pus formation

Pus formation is always a sign of infection with active tissue destructive processes taking place (Fig. 7.11). Peri-implantitis lesions usually yield some pus formation upon provocation by pressing on the mucosal tissues, while mucositis lesions may not. Hence, pus formation represents a specific diagnostic sign for the presence of peri-implantitis.

Radiographic interpretation

Conventional radiography

When using conventional radiographs for the evaluation of implant position in relation to anatomic structures and neighboring teeth, appropriate correction factors have to be considered for different radiographic techniques and positions within the oral cavity. Orthopantomograms generally demand a correction factor of 1:1.3, while periapical dental exposures are to be evaluated with a factor of between 1:1.0 and 1:1.1, depending on exposure geometry and differences in radiographic set-ups and sites. The long-cone parallel technique and positioning devices should be applied.

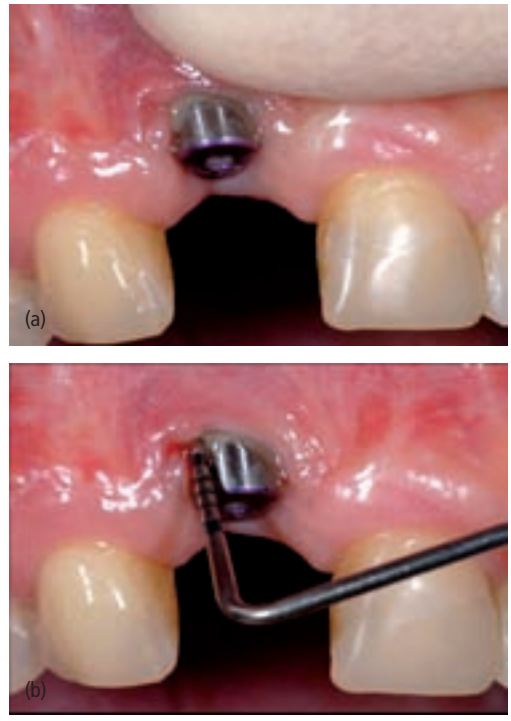


Fig. 7.11 Pus formation. (a) Pressure on the buccal mucosal aspect may result in a discharge of pus in sites of peri-implantitis. (b) A peri-implant probing depth of 9 mm documents the presence of peri-implantitis. (Courtesy of PD Dr N. Zitzmann.)

Conventional radiography is widely used in clinical practice to evaluate the bony structures adjacent to the implants over long periods (Fig. 7.12). However, it should be noted that minor changes in bone morphology in the crestal area may not be revealed until they reach a significant size and shape (45). In this respect, conventional radiography yields a high proportion of false-negative findings, and hence has a rather low sensitivity for detecting early pathologic and/or remodeling changes (46).

Nevertheless, the distance from the implant shoulder to the alveolar bone crest (DIB) represents a reliable radiographic parameter for long-term monitoring in clinical practice (47–49), provided that optimal exposure geometry has been achieved. Since the implant shoulder is usually placed 3 mm coronal to the alveolar crest for one-stage transmucosal implants, the difference between the various DIB values has to be considered over time. In two-stage submerged implant systems, however, the landmark to be used as a reference on the implant has to be defined clearly. Usually, the apical termination of the cylindrical part of implant fixtures is used. Conventional radiographs have a low proportion of false-positive findings and, hence, yield high specificity for the detection of peri-implant bone loss. However, this characteristic limits radiographs to being confirmatory rather than exploratory.

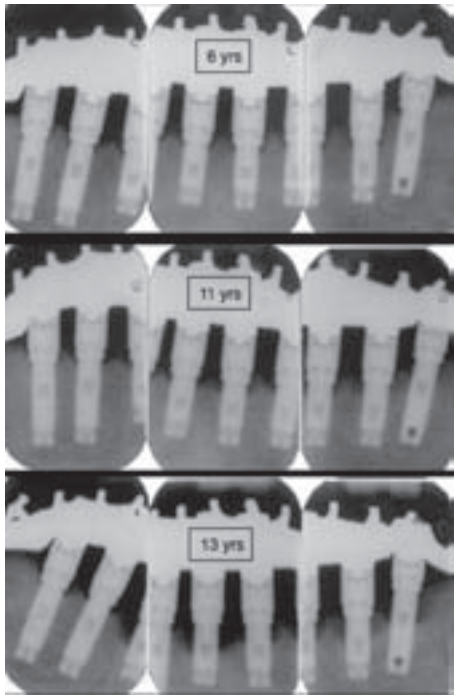


Fig. 7.12 Longitudinal radiographic documentation of developing peri-implantitis. Moderate bone loss after 11 and advanced bone loss after 13 years of function compared with 6 years after implant installation. In a recent study, 27.4% of the patients experienced peri-implantitis in 12.4% of the implants. (Adapted from Fransson *et al.* (44)).

It must be recognized that radiographic evidence of bone-to-implant contact does not imply osseointegration on a histologic level (50).

Digital subtraction radiography

In digitizing radiographs of identical exposure geometry, minute changes in the level and density of the alveolar bone may be revealed by subtracting subsequent images from a baseline radiograph. By doing this, the sensitivity of radiographs may be increased significantly (46). Hence, for clinical research, DSR is highly recommended and has been successfully applied in longitudinal studies (51).

Prophylactic procedures

Instruction in oral hygiene and patient motivation

Implant installation represents a series of therapeutic steps within the context of a comprehensive treatment plan with the goal being to reconstruct individually optimal function and esthetics. To provide a good long-term prognosis, the dentition has to be free of oral diseases before the actual implant installation. This, in turn, means that oral infections such as existing periodontal disease have to be treated before implant therapy. Plaque control is recognized as an integral part of periodontal treatment and forms the basis for the prevention of future disease (19).

The patient, therefore, should be motivated to perform an adequate level of plaque control on a regular basis. In general, the techniques to be taught to the patient for the cleaning of a dentition reconstructed with oral implants do not differ from those recommended for the natural dentition. However, special attention should be given to approximal cleaning, and the appropriate cleaning devices should be advocated for regular use.

Cleanable reconstructions

It is well established that overcontoured reconstructions, particularly in the proximal region, will prevent the patient from attaining optimal oral hygiene, thereby jeopardizing the health of abutment teeth and their surrounding tissues. Also, subgingivally placed reconstructions with imprecise margins will influence the composition of the subgingival microbiota (73), selecting for increased proportions of putative periodontal pathogens. Hence, reconstructions must meet high standards of marginal precision, especially in situations where esthetic aspects demand slightly subgingivally placed margins.

Furthermore, interproximal contours adjacent to abutment teeth or implants have to be shaped to accommodate appropriate cleaning devices. Although implant abutments are not susceptible to dental caries, peri-implant infections represent a risk for the longevity of an implant and have to be prevented by adequate plaque control practices.

Clinical implications

More recently, oral implants have begun to be installed in areas of esthetic priority. The preservation or recreation of papillae adjacent to implants and, above all, the submucosal placement of restorative margins to achieve optimal emergence profiles have gained attention. Although these compromises represent potential biologic hazards, it may be acceptable to satisfy the patient's esthetic needs or demands.

It must be realized, however, that precise marginal fit is a requisite. This may best be achieved through the use of screw-retained prefabricated copings, even though clinically acceptable marginal gaps may also be achieved with burn-out caps and well-performed castings which are cemented in place.

Maintenance care

After successful periodontal and implant therapy the patient should be offered a maintenance care program

adequately designed to fit his or her individual needs. It is important to ensure recall at regular intervals. This will provide optimal preventive services and facilitate the treatment of ongoing or emerging disease processes by providing appropriate supportive therapy.

A recall visit may be divided into four different phases:

- examination, re-evaluation, diagnosis
- motivation, reinstruction, instrumentation
- treatment of infected sites
- polishing, fluoridation, determining recall interval.

Therapeutic strategies

Cumulative interceptive supportive therapy

Depending on the clinical and the radiographic diagnosis, a protocol of therapeutic measures, called cumulative interceptive supportive therapy (CIST), has been designed to head off the development of peri-implant lesions (52). This protocol is cumulative in nature and includes four steps which should not be used as single procedures, but rather as a sequence of therapeutic procedures with increasing antibacterial potential, depending on the severity and extent of the lesion. Diagnosis, therefore, represents a key characteristic of this maintenance care program.

The major clinical parameters to be used have been discussed above and include assessment of the following (Fig. 7.13) (59):

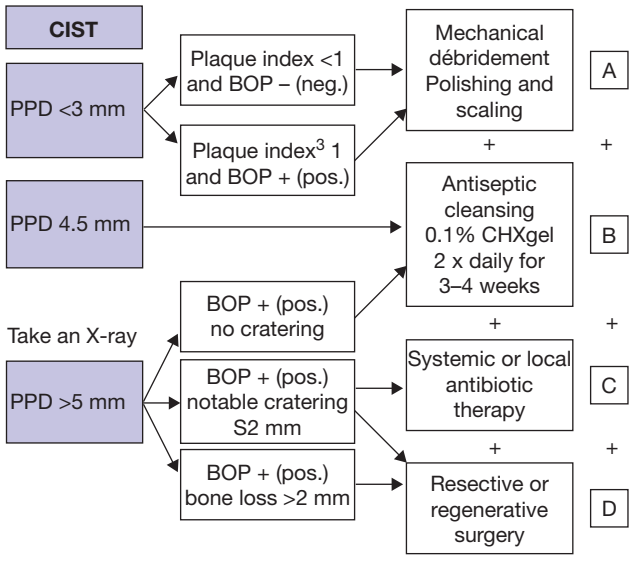


Fig. 7.13 Decision tree for cumulative interceptive supportive therapy (CIST). Depending on the mucosal condition and probing depth, either regime A, regime A+B, regime A+B+C, or regime A+B+C+D is performed. A: Mechanical débridement; B: antiseptic cleaning; C: antibiotic therapy; D: resective or regenerative surgery. (With permission of Lang & Lindhe (53).)

- presence or absence of dental plaque
- presence or absence of bleeding on gentle probing (BOP)
- presence or absence of suppuration
- peri-implant probing depth
- radiographic evidence of bone loss.

Oral implants without evident plaque or calculus adjacent to healthy peri-implant tissues – as revealed by absence of BOP, absence of suppuration, and probing depth usually not exceeding 3–4 mm – can be considered clinically stable and are not currently at risk for peri-implant disease. These implants should be re-evaluated at least on an annual basis. The frequency of and interval between supportive therapy visits should be determined by the patient's oral health status.

Mechanical débridement (supportive therapy protocol A)

Oral implants with evident plaque or calculus deposits adjacent to only slightly inflamed peri-implant tissues (BOP positive), but lacking suppuration and having a probing depth not exceeding 3–4 mm, are to be subjected to mechanical débridement. While calculus may be chipped off using carbon-fiber curettes (Hawe Neos, Bioggio, Switzerland), plaque is removed by means of polishing using rubber cups and polishing paste (e.g. Implaclinic®; Hawe Neos, Bioggio, Switzerland).

Carbon-fiber curettes do not sever the implant surface, but are sharp and strong enough to remove light to moderate calcified deposits on implants. Conventional steel curettes or ultrasonic instruments with metal tips leave marked damage on the implant surface (Fig. 7.14) and render it conducive to future plaque accumulation. They should not be used (54).

Removal of gross amounts of calculus, however, without touching the implant surface, is acceptable.

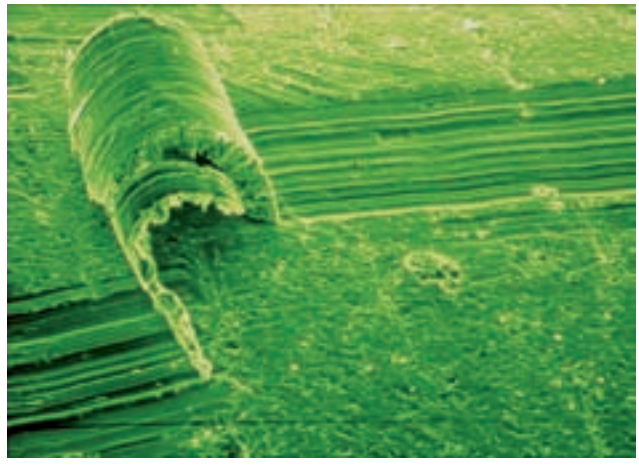


Fig. 7.14 Scanning electron micrograph depicting the result of one stroke with a steel curette on a pristine titanium implant surface. Substantial damage is demonstrated. (Adapted from Matarasso *et al.* (54).)

Antiseptic treatment (supportive therapy protocol B)

In addition to performing supportive therapy protocol A (i.e. mechanical débridement), antiseptic treatment is performed in situations where, in addition to the presence of plaque and BOP, probing depth is increased to 4–6 mm. Suppuration may or may not be present. The antiseptic treatment (protocol B) is performed in conjunction with the mechanical treatment (protocol A). Antiseptic treatment comprises the application of the most potent antiseptic available (55), i.e. chlorhexidine digluconate, either in the form of a daily rinse of 0.1%, 0.12%, or 0.2%, or as a gel applied to the site of desired action (Fig. 7.15). In general, 3–4 weeks of regular administration are necessary to achieve positive treatment results. Antiseptic rinses with chlorhexidine or applications of chlorhexidine gels may also be recommended for chemical plaque control on a preventive basis. This protocol has been validated both clinically and histologically in an animal experiment (56) and in humans (57).

Antibiotic treatment (supportive therapy protocol C)

When probing depth values of the peri-implant sulcus or pocket increase to 6 mm or more, plaque deposits and BOP are usually encountered. Suppuration may or may not be present. Such a peri-implant lesion is usually evident radiographically. The pocket with increased depth represents an ecologic niche which is conducive to colonization with Gram-negative anaerobic, periodontopathic microorganisms (11). The antibacterial treatment approach must then include antibiotics to eliminate or at least significantly reduce the pathogens in this submucosal ecosystem. This, in turn, will allow soft-tissue healing (58). Before administering antibiotics, the mechanical (A) and the antiseptic (B) treatment protocols have to be applied. During the last 10 days of the antiseptic treatment, an antibiotic directed at the elimination of Gram-negative anaerobic bacteria, e.g. metronidazole (Flagyl®, Rhône-Poulenc, 3 × 350 mg daily) or ornidazole (Tiberal®, Roche, 2 × 500 mg daily), is administered. These therapeutic steps have been validated in a clinical study (58) in which peri-implant infections were treated successfully and remained stable for a documented period of 1 year. Subsequently, prophylactic procedures were instituted to prevent reinfection.

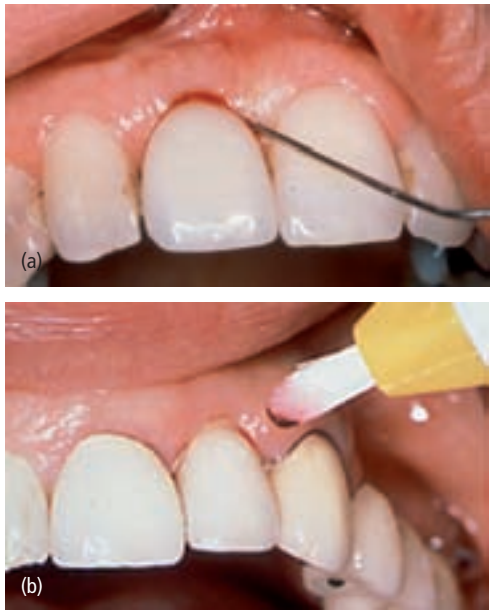


Fig. 7.15 Cumulative interceptive supportive therapy (CIST) – regimens A+B: mechanical and antiseptic cleaning. (a) Rinsing with chlorhexidine digluconate (0.12% twice a day) for 1 month. (b) Supplementing the rinses with the local application of chlorhexidine gel (0.2%) twice daily for 1 month.

As an alternative to administration of systemic antibiotics, the application of local antibiotics through the use of controlled delivery devices has emerged as a suitable treatment concept. However, only release devices with adequate release kinetics may be used to ensure successful clinical outcomes. The antibiotic must remain at the site of action for at least 7–10 days in a concentration high enough to penetrate the submucosal biofilm. As of today, only a limited number of products has been shown to demonstrate the appropriate characteristics (60).

Tetracycline periodontal fibers (Actisite®; Alza, Palo Alto, CA, USA) have successfully been applied in some case studies. The therapeutic effect appears to be identical to the effect documented for the systemic administration of antibiotics (61), provided that treatment protocols A and B are used as well. Hence, it appears that peri-implant infections may be controlled successfully by cumulatively providing mechanical, antiseptic, and antibiotic supportive therapy.

A more recently propagated control release device consists of microspheres containing minocycline hyclate (Arestin®; Johnson & Johnson) which are applied to the peri-implant pocket using a syringe (Fig. 7.16). These beads remain sticking to the implant surface and soft-tissue walls for at least 10 days and, hence, provide an ideal profile for a high-dose application at the site. Several clinical studies have documented the efficacy of the product on both the clinical (62–64) and the microbiologic level (62, 65). These microspheres appear to give similar outcomes in the treatment of peri-implantitis as does the systemic administration of antibiotics.

Regenerative or resective therapy (supportive therapy protocol D)

Only if infection is controlled successfully, as evidenced by an absence of suppuration and reduced edema, is it reasonable to discuss treatment approaches either to

restore the bony support of the implant by means of regenerative techniques or to reshape the peri-implant soft tissues and/or bony architecture by means of resective surgical techniques. Depending on the size and morphologic characteristics of the lesions as well as esthetic considerations a regenerative or a resective surgical procedure may be desirable. So far, single case presentations (66, 67) and animal studies (29, 68, 69) have provided evidence that bone fill of peri-implant defects resulting from previous peri-implantitis may be achieved following anti-infective therapy and using the biologic principle of guided tissue regeneration (Fig. 7.17). However, the reosseointegration of a previously contaminated implant surface into regenerated bone has only been demonstrated histologically for SLA implant surfaces (70) (Fig. 7.18). Nevertheless, the fact that new bone does fill osseous defects, as documented by an increase in radiographic bone density, represents a healing process most likely resulting in better implant stability over time.

Regarding attempts at local decontamination of the implant surface during surgical exposure, no conclusive evidence identifies one particular approach as being most effective. On the contrary, a well-controlled study in monkeys documented equality in the outcomes of bone fill and/or reosseointegration of peri-implant lesions (71). Hence, it appears that the microbiologic principle of dilution by irrigating the lesions under flap surgery, using chlorhexidine digluconate followed by

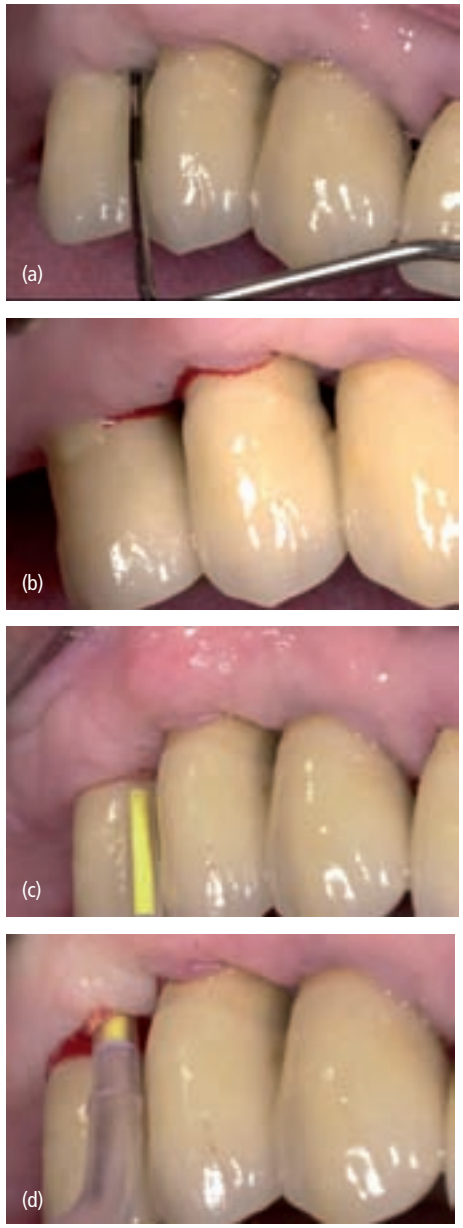


Fig. 7.16 Cumulative interceptive supportive therapy (CIST) – regimens A+B+C: mechanical and antiseptic cleaning plus administration of local antibiotics. (a) 6 mm peri-implant pocket with pus discharge. (b) Bleeding on probing and pus formation confirming the diagnosis of peri-implantitis. (c) Application of a controlled release device after mechanical and antiseptic cleaning. (d) Minocycline hyclate (microspheres) are sticking to the site after discharge from the applicator.

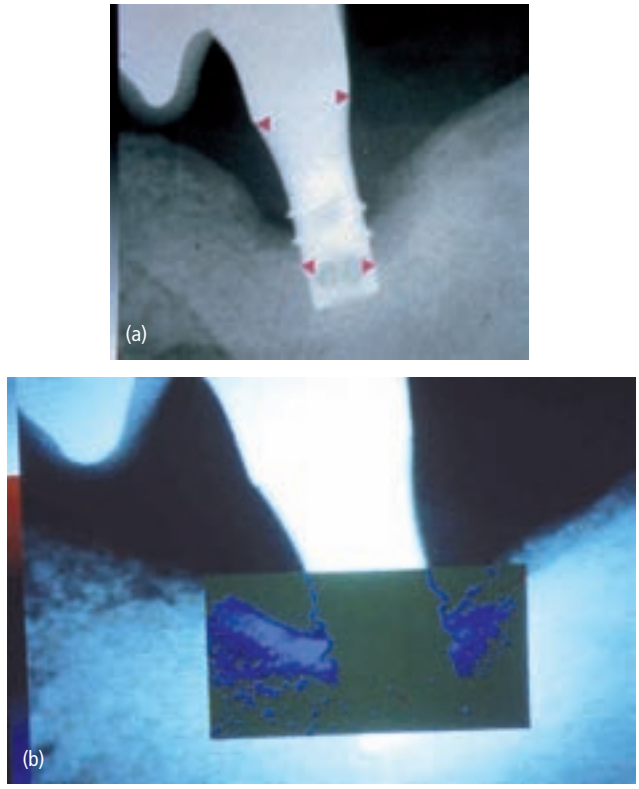


Fig. 7.17 Cumulative interceptive supportive therapy (CIST) – regimens A+B+C+D: mechanical, antiseptic cleaning, administration of systemic antibiotics plus regenerative surgical therapy. (a) Baseline radiograph of a peri-implantitis lesion extending to the apical 2 mm of a hollow screw implant. Red arrows indicate the extent of the lesion from the crown implant level (approximately 5–6 mm bone loss). (b) Subtraction radiographic image 1 year after treatment documenting approximately 3–4 mm of bone fill (blue: increase in radiographic density). (Adapted from Lehmann *et al.* (66).)

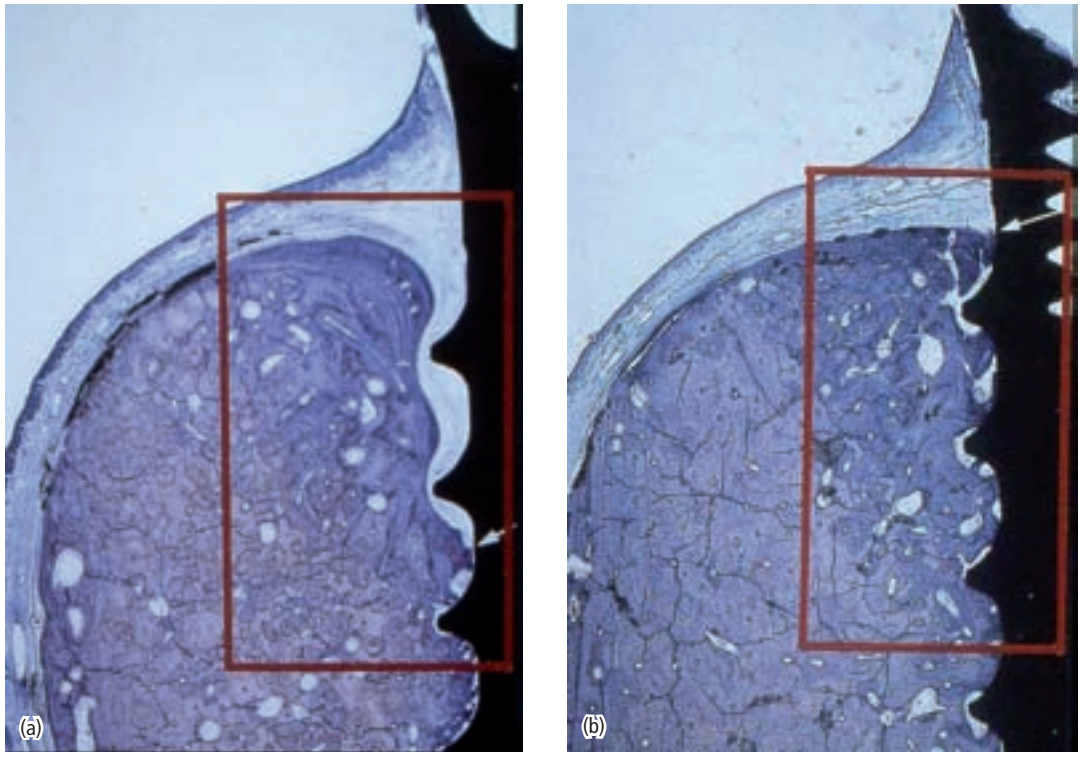


Fig. 7.18 Histologic documentation of cumulative interceptive supportive therapy (CIST) – regimens A+B+C+D: mechanical, antiseptic cleaning, administration of systemic antibiotics plus regenerative surgical therapy in a dog model. (a) Bone fill within the red frame (new bone in darker stain), but very limited reosseointegration in the apical portion of an experimental peri-implantitis lesion (white arrow) on a turned titanium implant surface. (b) Bone fill within the red frame (new bone in darker stain), but almost complete (> 80%) reosseointegration of an experimental peri-implantitis lesion (white arrow) on a microroughened (SLA) titanium implant surface. (Adapted from Persson *et al.* (70).)

sterile saline, is the most simple and effective protocol for surface decontamination (72). Occasionally, the clinician may find it appropriate to smooth and polish the supra-alveolar portion of the implant, although no beneficial effects of such a procedure have been documented.

Explantation

If a previously osseointegrated oral implant is clinically mobile, explantation is mandatory. The peri-implant lesion involves the entire length and circumference of the implant. Radiographically, this may be visible in a radiolucency surrounding the entire outline.

Explantation may also be necessary if the peri-implant infection has advanced to a degree where it cannot be controlled by the therapeutic protocols proposed above. Such a situation is clinically characterized by the presence of a suppurative exudate, overt BOP, and severely increased peri-implant probing depth (usually ≥ 8 mm), eventually reaching perforations or vents of hollow body implants, and may be associated with pain. Radiographically, a peri-implant radiolucency may be recognized extending far along the outline of the implant.

Conclusions and clinical implications

Oral implants are anchored in the jawbone and yet penetrate the mucosa, reaching the highly contaminated environment of the oral cavity. There, biofilms forming on all hard, non-shedding surfaces will also form on titanium implants. As on teeth, bacterial plaque will develop and trigger a host response, resulting in the development of mucositis. If plaque is allowed to accumulate over prolonged periods, peri-implant mucositis may develop into lesions extending farther apically, with associated loss of alveolar bone. Angular bony defects usually extending around the entire circumference of the implant may result, and are termed "peri-implantitis".

The peri-implant mucositis lesion is characterized by BOP and a peri-implant sulcus depth usually of 2–4 mm. Peri-implantitis, however, yields increasing probing depth usually exceeding 5 mm, with occasional suppuration and radiographic loss of crestal bone. However, clinical stability is not yet jeopardized, since the affected implant is not mobile as yet. Osseointegration in the apical portion of the implant usually persists.

Owing to the infectious nature of peri-implant mucositis and peri-implantitis, preventive procedures have to

be rendered in a well-organized recall program to assure adequate supportive therapy for a lifetime. Depending on continuing diagnosis during maintenance, developing peri-implant lesions should be treated according to the CIST protocols.

CIST includes as a first sequence mechanical, antiseptic, and antibiotic treatment to control ongoing infection. Following this, peri-implant bony lesions may be corrected by regenerative or resective surgical techniques. It is evident that preventive measures have to be reinstituted after such therapy.

Take-home hints

- Ensure that the patient is informed in detail about the possibility of developing inflammation and infection around implants.
- Diligently instruct the patient in oral hygiene practices with special emphasis on cleaning the implant sites.
- Require and organize a maintenance care system to recall the patient on a regular basis.
- Maintenance care should be provided at least once a year depending on the patient's past history and susceptibility for periodontitis.
- Realize that patients who experienced periodontitis are also at higher risk of developing peri-implant diseases. Hence, their recall interval ought to be shortened to 3–4 months.
- During maintenance or follow-up visits, use a periodontal probe to monitor probing depth, bleeding tendency, and possible suppuration.
- Intervene with prophylactic measures when mucositis (bleeding) is noted around the implant.
- View a pocket with a probing depth of 6 mm as an ecologic niche harboring anaerobic bacteria and, consequently, treat such lesions.
- Obtain a radiograph whenever the probing depth around an implant is 6 mm or more.
- Follow the recommendations for treatment according to the concept of cumulative interceptive supportive therapy (CIST).
- Do not intervene surgically without prior conservative, antibacterial therapy.
- Maintain optimal oral hygiene standards after peri-implantitis therapy.

References

1. Gristina AG. Biomaterial-centered infection: microbial adhesion versus tissue integration. *Science* 1987; **237**: 1588–95.
2. Mombelli A, Buser D, Lang NP. Colonization of osseointegrated titanium implants in edentulous patients. Early results. *Oral Microbiol Immunol* 1988; **3**: 113–20.
3. Mombelli A, Marxer M, Gaberthüel T, Grunder U, Lang NP. The microbiota of osseointegrated implants in patients with a history of periodontal disease. *J Clin Periodontol* 1995; **22**: 124–30.
4. Leonhardt AA, Renvert S, Dahlén G. Microbial findings at failing implants. *Clin Oral Implants Res* 1999; **10**: 339–45.
5. Fürst MM, Salvi GE, Lang NP, Persson GR. Bacterial colonization immediately after installation on oral titanium implants. *Clin Oral Implants Res* 2007; **18**: 501–8.
6. De Boever AL, De Boever JA. Early colonization of non-submerged dental implants in patients with a history of advanced aggressive periodontitis. *Clin Oral Implants Res* 2006; **17**: 8–17.
7. Quirynen M, Vogels R, Peeters W, van Steenberghe D, Naert I, Haffajee A. Dynamics of initial subgingival colonization of "pristine" peri-implant pockets. *Clin Oral Implants Res* 2006; **17**: 25–37.
8. Rams TE, Link CC. Microbiology of failing dental implants in humans: electron microscopic observations. *J Oral Implantol* 1983; **11**: 93–100.
9. Rams TE, Roberts TW, Tatum H Jr, Keyes PH. The subgingival microbial flora associated with human dental implants. *J Prosthet Dent* 1984; **51**: 529–34.
10. Krekeler G, Pelz K, Nelissen R. Mikrobielle Besiedlung der Zahnfleischtaschen am künstlichen Titanpfeiler. *Dtsch Zahnärztl Z* 1986; **41**: 569–72.
11. Mombelli A, Van Oosten MAC, Schürch E, Lang NP. The microbiota associated with successful or failing osseointegrated titanium implants. *Oral Microbiol Immunol* 1987; **2**: 145–51.
12. Apse P, Ellen RP, Overall CM, Zarb GA. Microbiota and crevicular fluid collagenase activity in the osseointegrated dental implant sulcus: a comparison of sites in edentulous and partially edentulous patients. *J Periodont Res* 1989; **24**: 96–105.
13. Leonhardt A, Berglundh T, Ericsson I, Dahlén G. Putative periodontal pathogens on titanium implants and teeth in experimental gingivitis and periodontitis in beagle dogs. *Clin Oral Implants Res* 1992; **3**: 112–19.
14. van Winkelhoff AJ, Goené RJ, Benschop C, Folmer T. Early colonization of dental implants by putative periodontal pathogens in partially edentulous patients. *Clin Oral Implants Res* 2000; **11**: 511–20.
15. Kronström M, Svenson B, Hellman M, Persson GR. Early implant failures in patients treated with Brånemark system titanium dental implants: a retrospective study. *Int J Oral Maxillofac Implants* 2001; **16**: 201–7.
16. Harris LG, Richards RG. *Staphylococcus aureus* adhesion to different treated titanium surfaces. *J Mater Sci Mater Med* 2004; **15**: 311–14.
17. Berglundh T, Lindhe J, Marinello C, Ericsson I, Liljenberg B. Soft tissue reaction to de novo plaque formation on implants and teeth. An experimental study in the dog. *Clin Oral Implants Res* 1992; **3**: 1–8.
18. Tonetti M, Schmid J. Pathogenesis of implant failures. *Periodontol 2000* 1994; **4**: 127–38.

19. Löe H, Theilade E, Jensen SB. Experimental gingivitis in man. *J Periodontol* 1965; **36**: 177–87.
20. Pontoriero R, Tonelli MP, Carnevale G, Mombelli A, Nyman SR, Lang NP. Experimentally induced peri-implant mucositis. A clinical study in humans. *Clin Oral Implants Res* 1994; **5**: 254–9.
21. Löe H. The gingival index, the plaque index and the retention index systems. *J Periodontol* 1967; **38** (Suppl): 610–16.
22. Mühlemann HR, Son S. Gingival sulcus bleeding – a leading symptom in initial gingivitis. *Helv Odontol Acta* 1971; **15**: 107–13.
23. Klinge B. Implants in relation to natural teeth. *J Clin Periodontol* 1991; **18**: 482–7.
24. Lindhe J, Berglundh T, Ericsson B, Liljenberg B, Marinello C. Experimental breakdown of peri-implant and periodontal tissues. A study in the dog. *Clin Oral Implants Res* 1992; **3**: 9–16.
25. Lang NP, Brägger U, Walther D, Beamer B, Kornman KS. Ligature-induced peri-implant infection in cynomolgus monkeys. I. Clinical and radiographic findings. *Clin Oral Implants Res* 1993; **4**: 2–11.
26. Schou S, Holmstrup P, Stolze K, Hjörting-Hansen E, Kornman KS. Ligature-induced marginal inflammation around osseointegrated implants and ankylosed teeth. Clinical and radiographic observations in cynomolgus monkeys (*Macaca fascicularis*). *Clin Oral Implants Res* 1993; **4**: 12–22.
27. Marinello CP, Berglundh T, Ericsson I, Klinge B, Glantz P-O, Lindhe J. Resolution of ligature-induced peri-implantitis lesions in the dog. *J Clin Periodontol* 1995; **22**: 475–9.
28. Ericsson I, Persson LG, Berglundh T, Edlund T, Lindhe J. The effect of antimicrobial therapy on periimplantitis lesions. An experimental study in the dog. *Clin Oral Implants Res* 1996; **7**: 320–8.
29. Persson LG, Ericsson I, Berglundh T, Lindhe J. Guided bone regeneration in the treatment of periimplantitis. *Clin Oral Implants Res* 1996; **7**: 366–72.
30. Gotfredsen K, Berglundh T, Lindhe J. Bone reactions at implants subjected to experimental peri-implantitis and static load. A study in the dog. *J Clin Periodontol* 2002; **29**: 144–51.
31. Gerber JA, Tan WC, Balmer TE, Salvi GE, Lang NP. Bleeding on probing and pocket probing depth in relation to probing pressure and mucosal health around oral implants. *Clin Oral Implants Res* 2009; **20**: 75–8.
32. Lang NP, Nyman S, Senn C, Joss A. Bleeding on probing as it relates to probing pressure and gingival health. *J Clin Periodontol* 1991; **16**: 257–61.
33. Karayiannis A, Lang NP, Joss A, Nyman S. Bleeding on probing as it relates to probing pressures and gingival health in patients with a reduced but healthy periodontium. A clinical study. *J Clin Periodontol* 1991; **19**: 471–5.
34. Lang NP, Joss A, Orsanic T, Gusberti FA, Siegrist BE. Bleeding on probing. A predictor for the progression of periodontal disease? *J Clin Periodontol* 1986; **13**: 590–6.
35. Lang NP, Adler R, Joss A, Nyman S. Absence of bleeding on probing. An indicator of periodontal stability. *J Clin Periodontol* 1990; **17**: 714–21.
36. Joss A, Adler R, Lang NP. Bleeding on probing. A parameter for monitoring periodontal conditions in clinical practice. *J Clin Periodontol* 1994; **21**: 402–8.
37. Luterbacher S, Mayfield L, Brägger U, Lang NP. Diagnostic characteristics of clinical and microbiological tests for monitoring periodontal and peri-implant mucosal tissue conditions during supportive periodontal therapy (SPT). *Clin Oral Implants Res* 2000; **11**: 521–9.
38. Löe H, Silness I. Periodontal disease in pregnancy. I. Prevalence and severity. *Acta Odontol Scand* 1963; **21**: 533–51.
39. Etter TH, Hakanson I, Lang NP, Trejo PM, Caffesse RG. Healing after standardized clinical probing of the periimplant soft tissue seal: a histomorphometric study in dogs. *Clin Oral Implants Res* 2002; **13**: 571–80.
40. Taylor A, Campbell M. Reattachment of gingival epithelium to the tooth. *J Periodontol* 1972; **43**: 281–93.
41. Christensen MM, Joss A, Lang NP. Reproducibility of automated periodontal probing around teeth and osseointegrated oral implants. *Clin Oral Implants Res* 1997; **8**: 455–64.
42. Lang NP, Wetzel AC, Stich H, Caffesse RG. Histologic probe penetration in healthy and inflamed periimplant tissues. *Clin Oral Implants Res* 1994; **5**: 191–201.
43. Ericsson I, Randow K, Glantz P-O, Lindhe J, Nilner K. Some clinical and radiographic features of submerged and non-submerged titanium implants. *Clin Oral Implants Res* 1994; **5**: 185–9.
44. Fransson C, Lekholm U, Jemt T, Berglundh T. Prevalence of subjects with progressive bone loss at implants. *Clin Oral Implants Res* 2005; **16**: 440–6.
45. Lang NP, Hill RW. Radiographs in periodontics. *J Clin Periodontol* 1977; **4**: 16–28.
46. Brägger U, Pasquali L, Rylander H, Carnes D, Kornman KS. Computer-assisted densitometric image analysis in periodontal radiography. A methodological study. *J Clin Periodontol* 1988; **15**: 27–37.
47. Buser D, Weber HP, Lang NP. Tissue integration of non-submerged implants. 1-year results of a prospective study with 100 ITI hollow-screw and hollow-cylinder implants. *Clin Oral Implants Res* 1990; **1**: 33–40.
48. Buser D, Weber HP, Brägger U, Balsiger C. Tissue integration of one-stage ITI implants. 3-year results of a longitudinal study with hollow-cylinder and hollow-screw implants. *Int J Oral Maxillofac Implants* 1991; **6**: 405–12.
49. Weber HP, Buser D, Fiorellini JP, Williams RC. Radiographic evaluation of crestal bone levels adjacent to non-submerged titanium implants. *Clin Oral Implants Res* 1992; **4**: 181–8.
50. Sewerin IP, Gotfredsen K, Stoltze K. Accuracy of radiographic diagnosis of periimplant radiolucencies – an *in vitro* experiment. *Clin Oral Implants Res* 1997; **8**: 299–304.
51. Brägger U, Hugel-Pisoni C, Bürgin W, Buser D, Lang, NP. Correlations between radiographic, clinical and mobility parameters after loading of oral implants with fixed partial dentures: a two-year longitudinal study. *Clin Oral Implants Res* 1996; **7**: 230–9.
52. Lang NP, Berglundh T, Heitz-Mayfield LJ, Pjetursson BE, Salvi GE, Sanz M. Consensus statements and recommended clinical procedures regarding implant survival and complications. *Int J Oral Maxillofac Implants* 2004; **19**: 150–4.

53. Lang NP, Lindhe J. Maintenance of the implant patient. In: Lang NP, Lindhe J, eds. *Clinical periodontology and implant dentistry*. Vol. 2: *Clinical concepts*, 5th edn. Oxford: Wiley Blackwell, 2008: Chapter 60.
54. Matarasso S, Quaremba G, Coraggio F, Vaia E, Cafiero C, Lang NP. Maintenance of implants: an *in vitro* study of titanium implant surface modifications subsequent to the application of different prophylaxis procedures. *Clin Oral Implants Res* 1996; **7**: 64–72.
55. Lang NP, Brecx M. Chlorhexidine digluconate: an agent for chemical plaque control and prevention of gingival inflammation. *J Periodont Res* 1986; **21**: (Suppl 18): 74–89.
56. Trejo PM, Bonaventura G, Weng D, Caffesse RG, Brägger U, Lang NP. Effect of mechanical and antiseptic therapy on peri-implant mucositis: an experimental study in monkeys. *Clin Oral Implants Res* 2007; **17**: 294–304.
57. Porras R, Anderson GB, Caffesse R, Narendran S, Trejo PM. Clinical response to 2 different therapeutic regimens to treat peri-implant mucositis. *J Periodontol* 2002; **73**: 1118–25.
58. Mombelli A, Lang NP. Anti-microbial treatment of peri-implant infections. *Clin Oral Implants Res* 1992; **3**: 162–8.
59. Mombelli A, Lang NP. Clinical parameters for the evaluation of dental implants. *Periodontol 2000* 1994; **4**: 81–6.
60. Tonetti MS. Local delivery of tetracycline: from concept to clinical application. *J Clin Periodontol* 1998; **25**: 969–77.
61. Mombelli A, Lang NP. The diagnosis and treatment of peri-implantitis. *Periodontol 2000* 1998; **17**: 63–76.
62. Renvert S, Lessem J, Dahlén G, Lindahl C, Svensson MJ. Topical minocycline microspheres versus topical chlorhexidine gel as an adjunct to mechanical débridement of incipient peri-implant infections: a randomized clinical trial. *J Clin Periodontol* 2006; **33**: 362–9.
63. Renvert S, Lessem J, Dahlén G, Renvert H, Lindahl C. Mechanical and repeated antimicrobial therapy using a local drug delivery system in the treatment of peri-implantitis: a randomized clinical trial. *J Periodontol* 2008; **79**: 836–44.
64. Salvi GE, Persson GR, Heitz-Mayfield LJ, Frei M, Lang NP. Adjunctive local antibiotic therapy in the treatment of peri-implantitis. II: Clinical and radiographic outcomes. *Clin Oral Implants Res* 2007; **18**: 281–5.
65. Persson GR, Salvi GE, Heitz-Mayfield LJ, Lang NP. Antimicrobial therapy using a local drug delivery system (Arestin) in the treatment of peri-implantitis. I: Microbiological outcomes. *Clin Oral Implants Res* 2006; **17**: 386–93.
66. Lehmann B, Brägger U, Hämmerle CHF, Fourmousis I, Lang NP. Treatment of an early implant failure according to the principles of guided tissue regeneration. *Clin Oral Implants Res* 1992; **3**: 42–8.
67. Hämmerle CHF, Fourmousis I, Winkler JR, Weigel C, Brägger U, Lang NP. Successful bone fill in late peri-implant defects using guided tissue regeneration. A short communication. *J Periodontol* 1995; **66**: 303–8.
68. Persson LG, Araújo MG, Berglundh T, Gröndahl K, Lindhe J. Resolution of peri-implantitis following treatment. An experimental study in the dog. *Clin Oral Implants Res* 1999; **10**: 195–203.
69. Wetzel AC, Vlassis J, Caffesse RG, Hämmerle CHF, Lang NP. Attempts to obtain re-osseointegration following experimental peri-implantitis in dogs. *Clin Oral Implants Res* 1999; **10**: 111–19.
70. Persson LG, Berglundh T, Lindhe J, Sennerby L. Re-osseointegration after treatment of peri-implantitis at different implant surfaces. An experimental study in the dog. *Clin Oral Implants Res* 2001; **12**: 595–603.
71. Schou S, Holmstrup P, Jørgensen T, Skovgaard LT, Stoltze K, Hjørting-Hansen E, Wenzel A. Implant surface preparation in the surgical treatment of experimental peri-implantitis with autogenous bone graft and ePTFE membrane in cynomolgus monkeys. *Clin Oral Implants Res* 2003; **14**: 412–22.
72. Schou S, Berglundh T, Lang NP. Surgical treatment of peri-implantitis. *Int J Oral Maxillofac Implants* 2004; **19** (Suppl): 140–9.
73. Lang NP, Kiel RA and Anderhalden K. Clinical and microbiological effects of subgingival restorations with overhanging or clinically perfect margins. *Journal of Clinical Periodontology* 1983; **10**: 563–78.

Chapter 8

Esthetic complications due to implant malpositions: etiology, prevention, and treatment

Stephen T. Chen BDS, MDSc, PhD and Daniel Buser DDS, Prof.Dr.Med.Dent.

Introduction

In the past 10 years, a rapid expansion of implant therapy has taken place in the field of reconstructive dentistry. This expansion has been facilitated by good scientific long-term documentation of dental implants, new or improved biomaterials such as implant surfaces, bone substitutes or barrier membranes, and the development of improved treatment concepts, which offer better treatment outcomes, shorter healing periods, and less morbidity for patients. Although the predictability of dental implants has improved, their increasing utilization for the rehabilitation of fully and partially edentulous patients will inevitably result in an increase in the number and severity of implant-related complications and failures. Thus, the diagnosis and treatment of implant complications will become a dominating issue for clinicians active in the field of implant dentistry. In order to prevent such complications, it is also important to understand the causes of implant complications.

Potential causes of implant complications are related to four factors that influence the treatment outcome of implant therapy (Fig. 8.1). These four factors have been described by Buser and Chen (1) for implant placement in postextraction sites, but they can be applied to implant therapy in general. In this context, the clinician plays the most important role in the prevention of implant complications, since the clinician (i) evaluates the patient before implant therapy using a detailed risk assessment, (ii) selects appropriate biomaterials including the implant itself, bone grafts or bone substitutes as well as barrier membranes if bone augmentation procedures are required, (iii) selects an appropriate treatment approach that should offer a successful outcome with high predict-

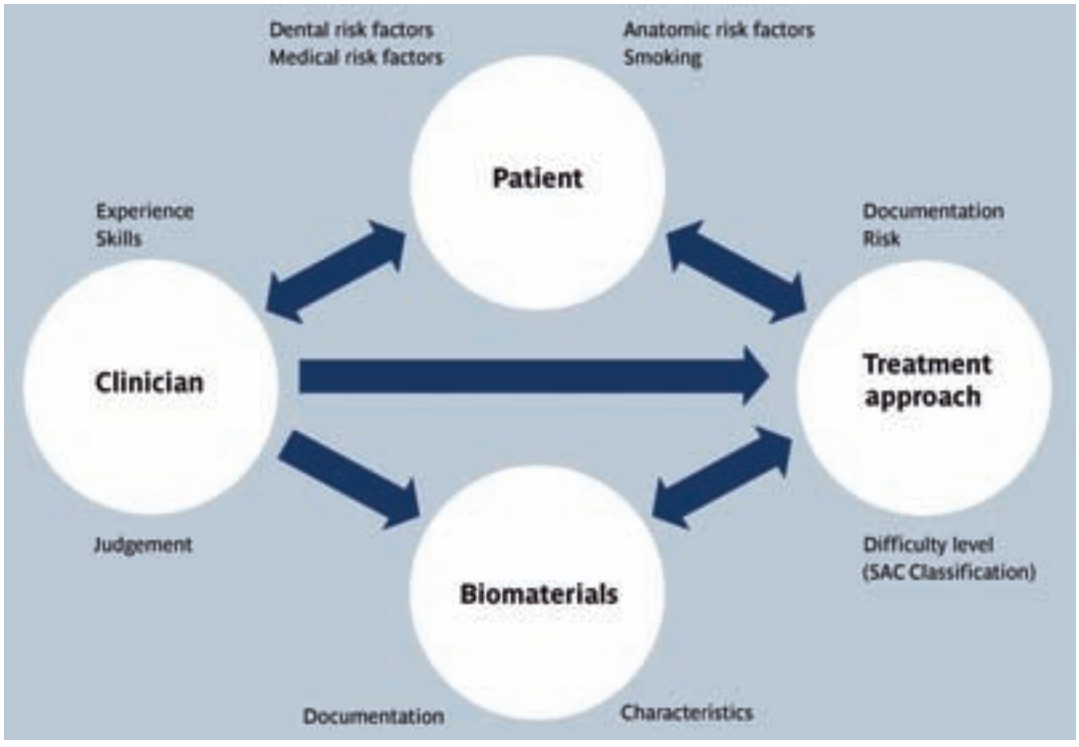


Fig. 8.1 Diagram illustrating the interrelationship between the four principal factors that influence the outcome of implant therapy.

ability and a low risk of complications, (iv) carries out the treatment, and (v) is responsible to the patient for diagnosing and managing complications during the important maintenance period. While recognizing the significance of patient-related factors, it is obvious that the clinician bears a lot of responsibility for the prevention of implant complications, particularly in the planning and treatment phase where many complications have their genesis when inappropriate clinical decisions are made.

Esthetic complications are especially demanding for the clinician, since they are often associated with strong emotive responses from patients and are difficult to resolve. Esthetic complications can be caused either by malpositioned implants, inappropriate number and/or size of utilized implants, or peri-implant infection progressively leading to the destruction of peri-implant bone, or by existing bone or soft-tissue deficiencies in the alveolar process. These factors can have a close relationship with each other. In this chapter, the focus will be on esthetic complications caused by malpositioned implants.

Esthetic complications due to implant malpositions

In the field of implant dentistry, clinicians started to focus more on esthetic outcomes in the early 1990s. This development was initiated by the first textbook on this subject written by Parel and Sullivan (2). In the mid 1990s, clinicians began to have a much better understanding of the tissue biology around endosseous implants. More importantly, it was understood that the concept of the biologic width also applies around endosseous implants, as it does around natural teeth (3–5). As a consequence, the significance of bone to support the soft tissues was understood for the achievement of esthetic outcomes in the anterior maxilla. In addition, the importance of a correct three-dimensional (3D) implant placement was recognized, from which the term "restoration-driven implant placement" was established (6, 7). It was realized that the placement of implants must follow prosthetic needs to achieve the anticipated treatment outcome.

Based on the results of the Third ITI Consensus Conference held in 2003 in Gstaad, Switzerland, the "concept of comfort and danger zones" was introduced for the placement of dental implants in the esthetic zone (8). The main purpose of this concept was to sensitize clinicians to avoid the placement of implants in the danger zones, since this can result in severe esthetic complications. These comfort and danger zones (Fig. 8.2a–c) have been defined in three directions: mesiodistally, coronoapically, and orofacially. In the following subsections, malpositions in these three directions will be discussed and documented with case reports to illustrate their potential for esthetic complications.

Mesiodistal malposition

An implant is positioned inside the mesiodistal danger zone when the implant is placed too close to an adjacent tooth (Fig. 8.2a). Such a position can cause a reduced papilla at the adjacent tooth, and was first described by Esposito *et al.* in 1993 (9). This complication is mainly caused by the development of a crestal bone modeling process during healing and after implant restoration. This biologic phenomenon is routinely observed around commonly used implants such as the Brånemark system or the Straumann implant system, and results in what is often termed a "bone saucer". This saucer has a horizontal component of 1.0–1.5 mm, whereas the vertical component measures around 2–3 mm (Fig. 8.3). Thus, the clinician has to keep a distance of at least 1.0 mm or preferably 1.5 mm to the root surface to avoid such a complication. If an implant is placed too close to a root surface, a reduced papilla height will result, since there is not enough space for the soft tissues to develop (Fig. 8.4). These complications are often caused by an inappropriate implant diameter, e.g. an oversized implant with a platform too large for a single tooth gap. An oversized implant can also cause an impaired esthetic outcome, if it is used in lateral incisor sites. Such situations cause a disturbed emergence profile of the implant restoration, although the correct mesiodistal position is only altered by approximately 1 mm (Fig. 8.5a, b).

In some situations, although an implant with a correct shoulder diameter has been selected for the available space, local anatomic structures may result in the implant being placed too close to an adjacent tooth. This is often encountered in maxillary central incisor sites when the location of a prominent nasopalatine canal may cause the implant to be placed distally in the space, with subsequent blunting of the papilla (Fig. 8.4).

When the mesiodistal malposition of the implant is extreme and differs by 2–3 mm from the ideal prosthetic position, this can lead to significant and permanent loss of hard- and soft-tissue support with extremely adverse esthetic outcomes (Fig. 8.6a, b).

Coronoapical malposition

A coronoapical malposition can cause two different complications (Fig. 8.2b). If the implant is not inserted deep enough into the tissues, the metal implant shoulder can be visible, causing an unpleasant esthetic outcome, although no recession of the mucosa is present. This coronal malposition has been observed only in rare cases, in particular with tissue-level implants (Fig. 8.7).

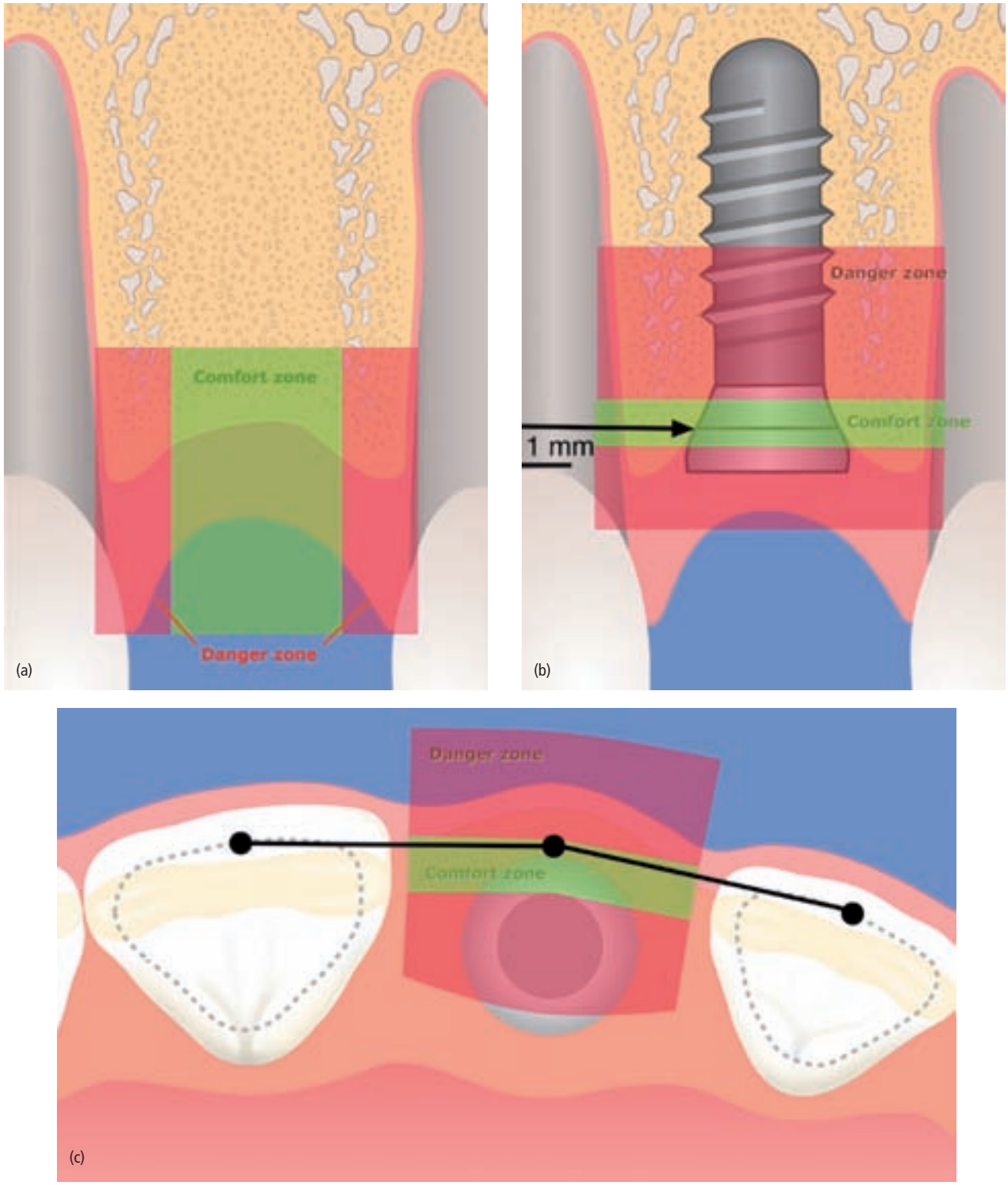


Fig. 8.2 (a) The concept of "comfort" and "danger" zones for the position of implants in relation to the adjacent natural teeth. In a mesiodistal dimension, the implant should be positioned within the comfort zone (green zone). The danger zone is 1.0–1.5 mm wide. (b) Apicocoronally, the implant shoulder should be positioned about 1 mm apical to the cementoenamel junction (CEJ) of the contralateral tooth in patients without gingival recession. The danger zone is entered when the implant shoulder is placed too deeply or too coronally in relation to the comfort zone (green zone). (c) In the orofacial plane, the facial extent of the implant shoulder is about 1 mm orally to the point of emergence of the adjacent teeth (within the green comfort zone). The implant enters the danger zone when the shoulder is placed too facially: this increases the risk of mucosal recession. The implant should not be placed too far orally either.

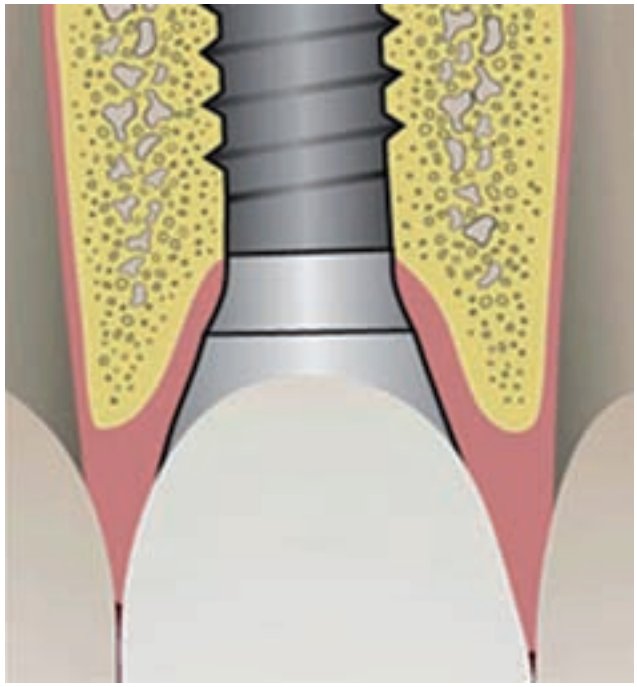
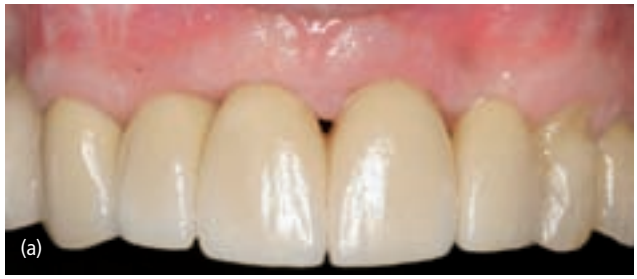


Fig. 8.3 Schematic drawing of an implant with the typical pattern of crestal bone resorption, called a "bone saucer". The saucer has a horizontal component of at least 1 mm and a vertical component of 2–3 mm.



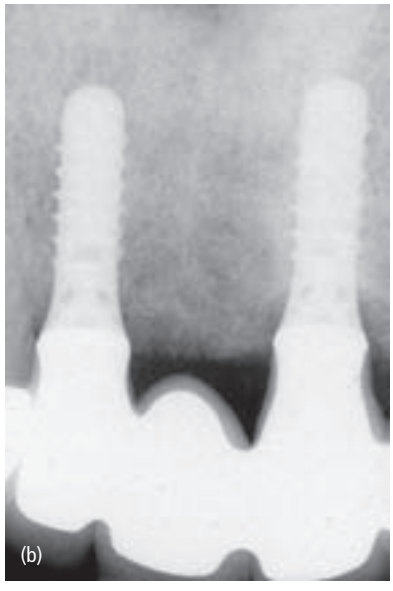


Fig. 8.5 (a) Four-unit, fixed dental prosthesis, supported by two implants in area 7 and 9. The esthetic outcome in area 7 is compromised, since an inappropriate implant platform has been selected. (b) A narrow neck implant would have been a correct choice in area 7. The smaller implant platform would have offered a better emergence profile with a better esthetic outcome.

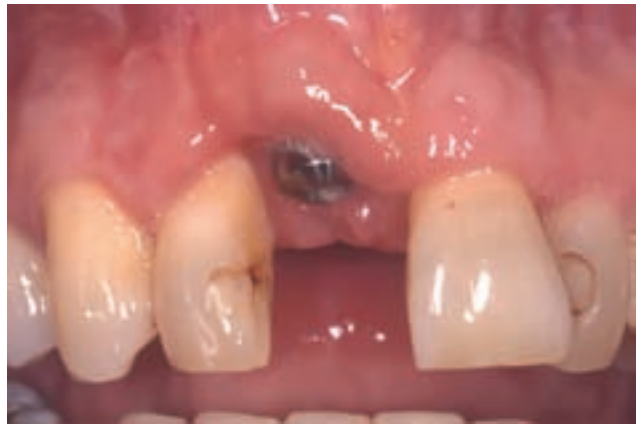
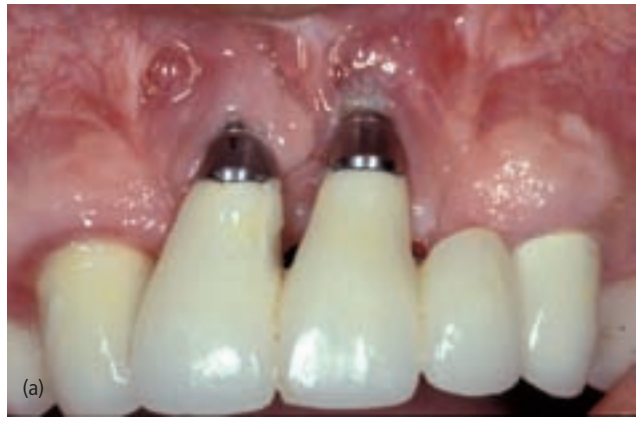


Fig. 8.4 Owing to the location of the nasopalatine canal, this implant has been placed too close to the adjacent lateral incisor, resulting in loss of the papilla.



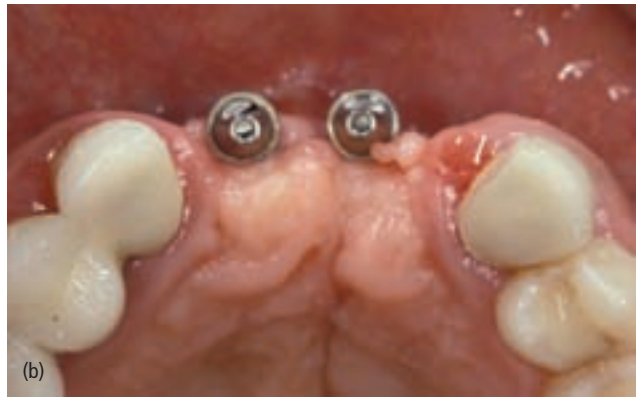


Fig. 8.6 (a) There is a major discrepancy in the midline of this implant-borne restoration in the anterior maxilla. Three crowns have been used to restore a space with four missing teeth. The two implants are malpositioned in the mesiodistal direction. This has led to major problems in restoring the edentulous space with a fixed dental prosthesis (FDP). (b) Status after removal of the FDP. The occlusal view clearly shows the mesiodistal malposition of both implants. Both implants should have been positioned about 2 mm farther to the left side.

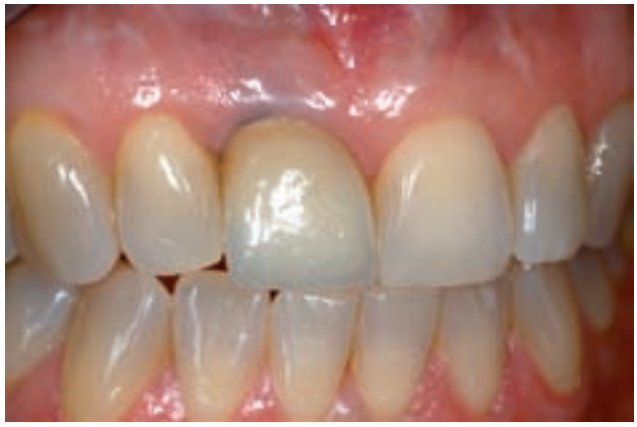
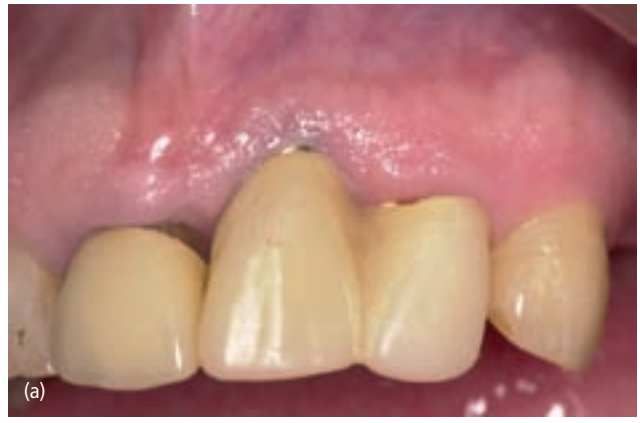


Fig. 8.7 The tissue level implant in site 8 has been placed too shallow in an apicocoronal plane. As a result, the metal margin of the implant collar is visible.



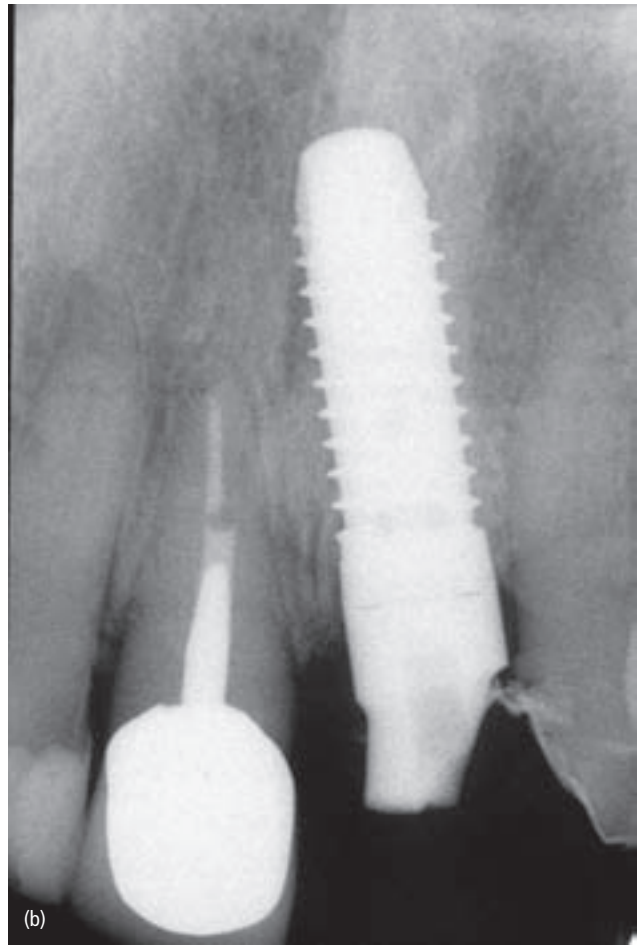
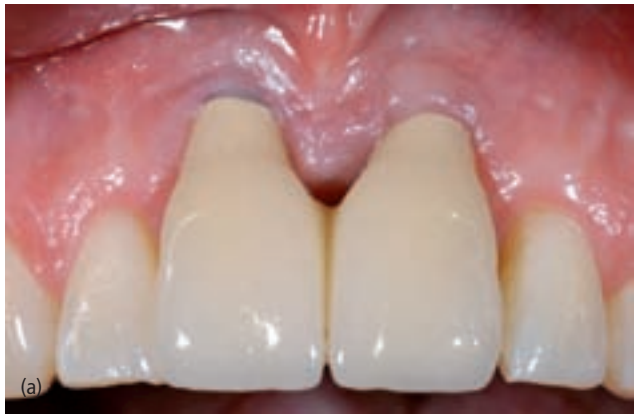


Fig. 8.8 (a) A severe esthetic complication with a recession of the facial mucosa at implant 9, which was placed as an immediate implant after extraction of tooth 9. The harmony of the gingival line is completely disrupted. In addition, both peri-implant papillae are reduced in height. (b) The periapical radiograph shows that the implant was inserted in an apical malposition, roughly 2 mm too deep. In addition, the incorrect axis of the implant resulted in a position too close to the adjacent tooth 10, leading to the complete loss of the papilla.

The more common complication is an implant that is placed too deep into the tissues. This apical malposition can cause recession of the facial mucosa, if the implant only has a thin facial bone wall at implant placement (Fig. 8.8a, b). Following restoration, this thin bone wall is resorbed during the bone modeling process, since the already discussed bone saucer is a circumferential phenomenon. This leads to bone resorption not only at the mesial and distal aspect of the implants, as seen on the radiograph, but also on the facial and palatal aspect. Bone resorption on the facial aspect can lead within a few weeks to a recession of the facial mucosa (Fig. 8.9a, b). In the early 1990s it was recommended to place Brånemark type implants 3–4 mm below the cementoenamel junction (CEJ) of adjacent teeth (2). It can be assumed that this coronoapical implant position in most patients caused a certain degree of recession of the mucosa after the bone modeling phase, as shown in a clinical study by Small and Tarnow (10). The authors reported the development of a mucosal recession in about 80% of the patients, on average of about 1 mm. The recession can be more pronounced if an apical malposition is combined with a facial malposition.

Orofacial malposition

An orofacial malposition of an implant can also cause two different complications (Fig. 8.2c). The first complication occurs if the implant is positioned too far palatally. This will often lead to a ridge-lap design of the implant crown. While this does not always lead to an esthetic complication, it may make it difficult for the patient to maintain optimum plaque control, with subsequent long-term implications for the health of the peri-implant tissues. If the palatal malposition is combined with deep placement, it can sometimes be difficult to seat the abutment because of the thick facial and palatal mucosa (Fig. 8.10a–c). Patients may also complain that the palatal surface of the implant crown feels bulky.



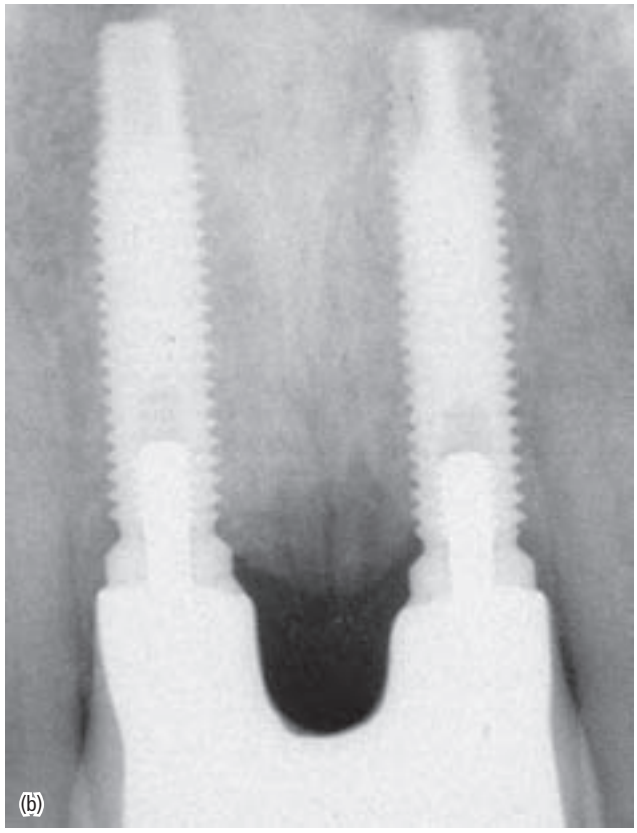
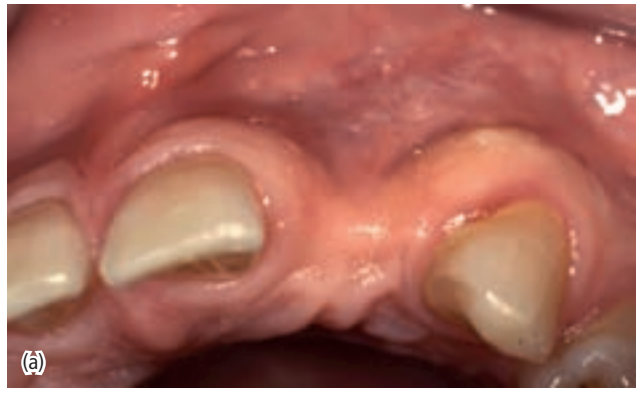
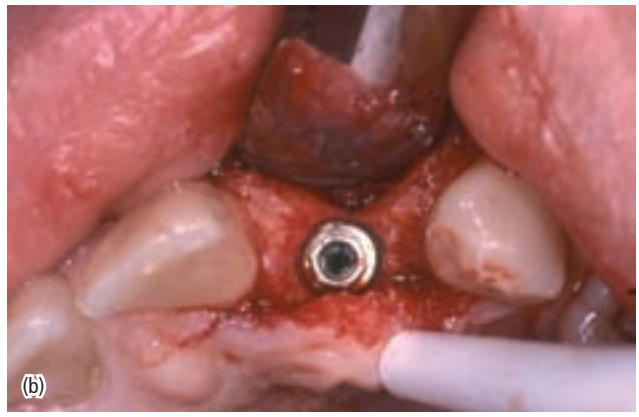


Fig. 8.9 (a) Severe esthetic complication with a recession of the facial mucosa at implants 8 and 9, which were placed as immediate implants after extraction. Both implants were inserted too deep into an apical malposition. As a result, both implant crowns are too long owing to the mucosal recession. In addition, the interimplant papilla is clearly reduced. (b) The periapical radiograph confirms the apical malposition and the horizontal bone resorption between both implants. Both are the main causes of the esthetic complication.





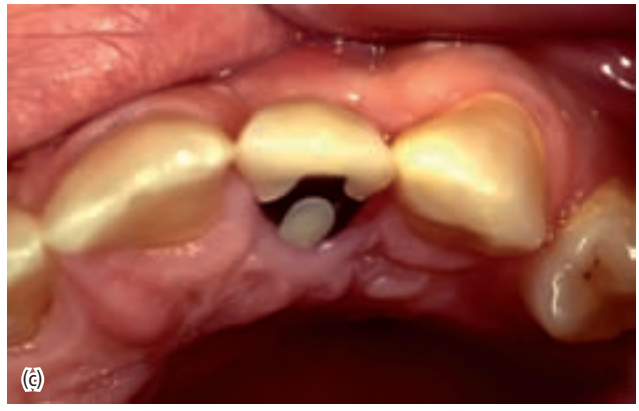


Fig. 8.10 (a) Pretreatment occlusal view of the upper left lateral incisor site showing marked orofacial resorption of the ridge. (b) Intraoperative view of an implant in the 10 position. Sufficient orofacial bone width was present to allow the implant to be placed, but in a palatal position in relation to the dental arch. (c) Occlusal view of the implant restoration showing the palatal eminence of the crown and palatally positioned access screw hole. The crown loosened on several occasions owing to improper seating as a result of the deep and palatal placement, and thick soft-tissue cuff. The crown/abutment could only be inserted correctly following reflection of a palatal flap.

The second complication is a recession of the facial mucosa if the implant is clearly positioned too far facially. This can cause severe esthetic complications, since the harmonious gingival course is significantly disturbed and often requires the removal of the implant (Fig. 8.11a, b). These complications have frequently been observed in patients with immediately placed implants. This treatment approach in postextraction sites bears an increased risk for mucosal recession, as documented in various retrospective and prospective clinical studies (11–16). Some of these studies clearly showed that the facial malposition is a risk factor for the development of a

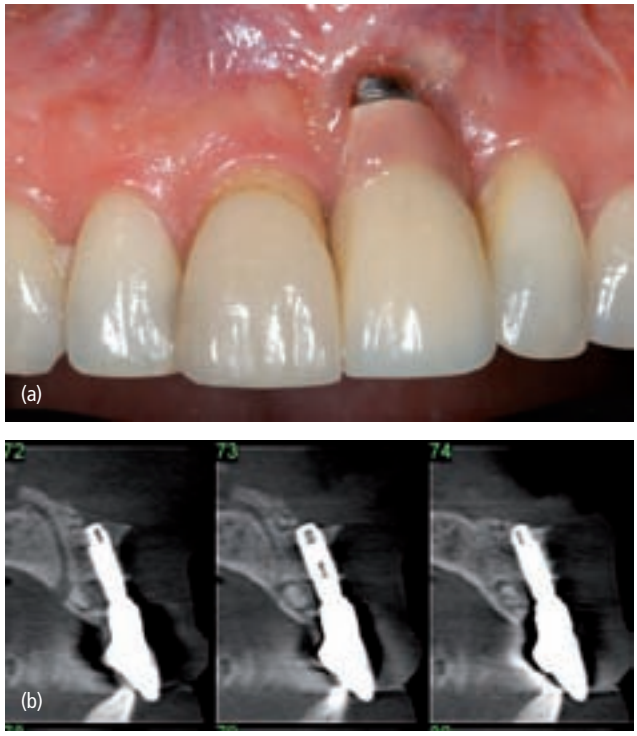


Fig. 8.11 (a) A severe recession of the mucosa has occurred owing to a facial malposition of the implant in the upper left central incisor site (site 9). (b) Cone beam computed tomographic scan of the implant showing the facial malposition of the implant.

mucosal recession (13, 16). It may be speculated that the shape of a fresh extraction socket often guides an implant into that malposition during implant insertion. This risk is further increased if an oversized, wide-platform implant is used with such a surgical approach (Fig. 8.12a, b), as has been recommended in the past to obliterate the socket with a large diameter implant (17).

Axis problems with endosseous implants

A further possibility for an esthetic complication occurs when an implant is inserted with an axis problem. Implants that are inclined too far facially are often associated with recession of the facial mucosa. If the axis problem is minor and the shoulder of the implant lies within the comfort zones, the axis problem can usually be corrected by prosthetic means using angled abutments which are available for most implant systems. If the axis problem is severe and if it is combined with a facial malposition of the implant shoulder the esthetic complication is usually very difficult or impossible to resolve (Fig. 8.13a–c). In some cases, the axis can be corrected by segmental osteotomy and repositioning of the implant (18). However, in the majority of cases, the most effective treatment is to remove the implant, augment the site, and place a new implant in the correct position.

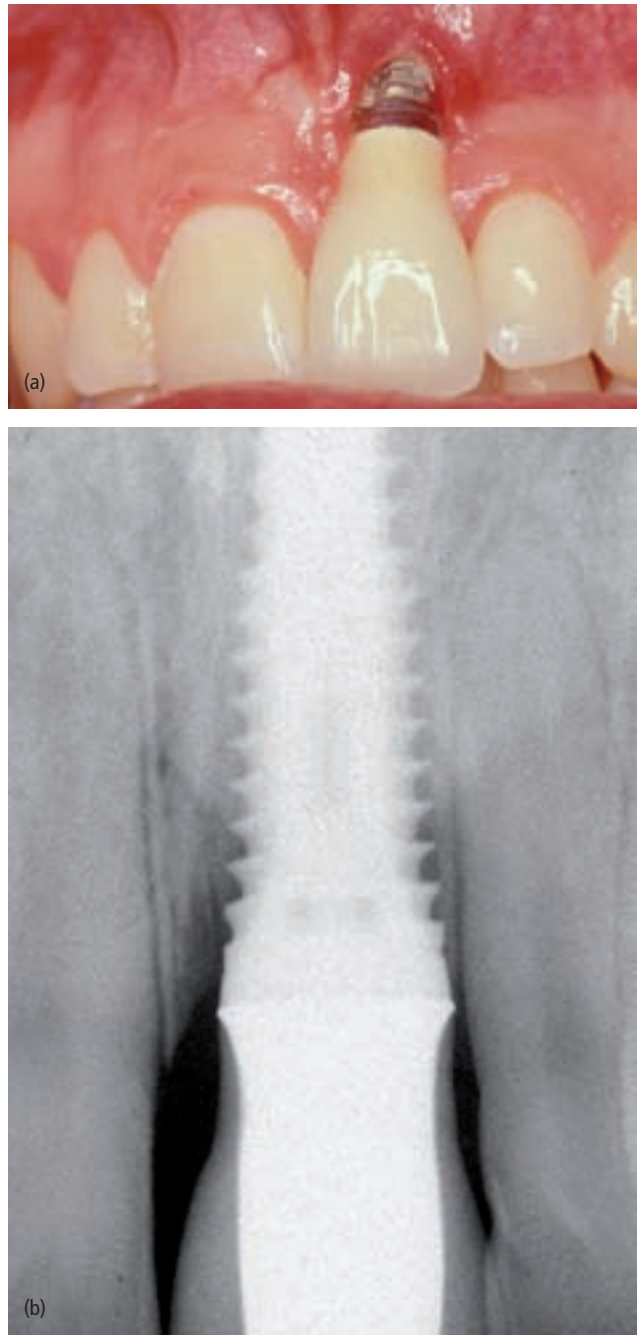


Fig. 8.12 (a) A disaster case with a severe facial recession and an exposed implant surface. The implant, placed as an immediate implant after extraction, is facially and apically malpositioned. (b) The periapical radiograph shows that the inserted, tapered implant was too large. Such a wide platform implant makes a facial malposition even worse.

Prevention of implant malposition

Importance of clinical experience and surgical skills

To achieve an optimal esthetic treatment outcome, various factors must be optimized or fulfilled as already

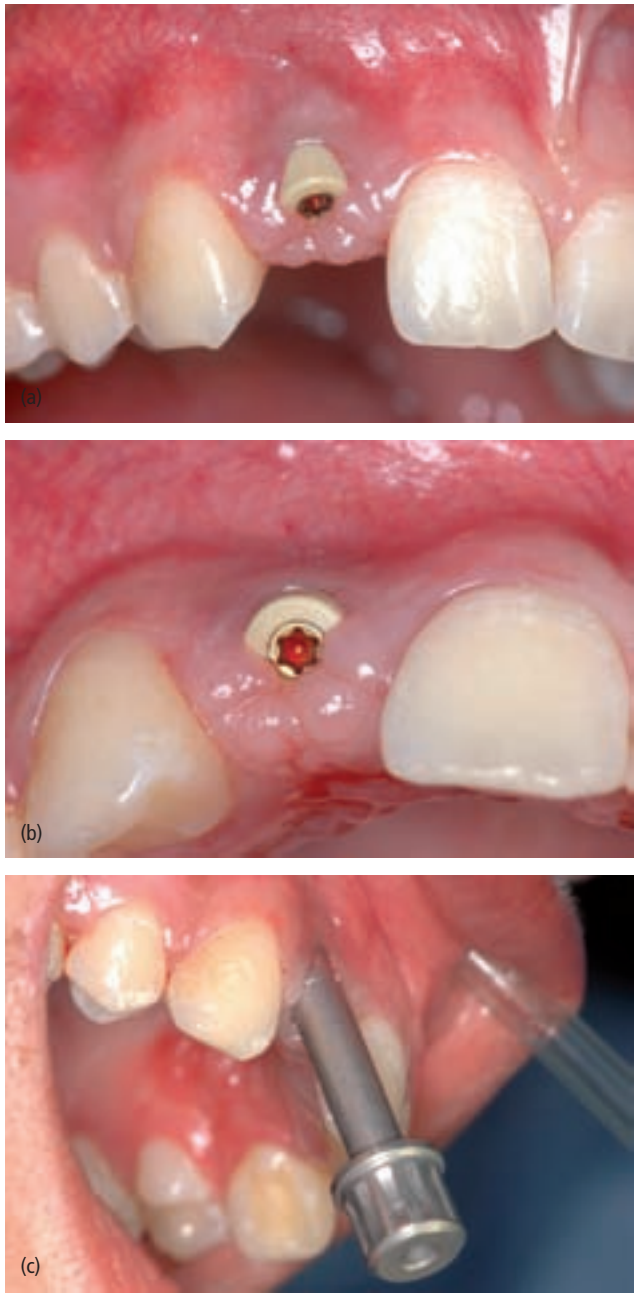


Fig. 8.13 (a) Malpositioned implant in a lateral incisor site. The implant with a healing cap shows a minor recession of the facial mucosa. (b) The occlusal view clearly shows that the implant is positioned in a facial malposition. (c) In addition, the implant has a severe axis problem, as indicated by the mounted removal device.

shown in Fig. 8.1. Implant placement in a correct 3D position is primarily influenced by the clinician and by the selection of an appropriate implant type. Here, the diameter of the implant platform is the important factor. As already discussed above, oversized implants with a wide platform should be avoided in esthetic implant sites, since they increase the risk of encroaching into the facial or mesiodistal danger zones. As a consequence, regular-platform implants with diameters between 4.0 and 5.0 mm are routinely used in daily practice. In lateral incisor sites, narrow-platform implants with diameters between 3.0 and 3.5 mm are often indicated. Implant insertion in a correct 3D position is only one important prerequisite for successful esthetic outcomes. The other prerequisite is to rebuild a sufficient volume of peri-implant tissues on the facial aspect of the implant to achieve a pleasing esthetic result. With the current knowledge of implant esthetics, the main emphasis for many clinicians is bone augmentation on the facial aspect of the implant. In esthetic areas, the majority of implants require contour augmentation on the facial aspects, since (i) a facial atrophy is most often present in healed sites, (ii) bone modeling activities will lead to the resorption and flattening of the facial contour in postextraction sites, and (iii) the facial bone provides support for the peri-implant mucosa.

The insertion of implants in a correct 3D position and the augmentation of bone on the facial aspect require both surgical skills and sufficient clinical experience. To be a successful implant surgeon, several factors need to be considered. The clinician must possess the clinical skills and competence to undertake a given surgical implant procedure with precision. The attainment of this appropriate level of skill and competence should be based on proper education, preferably in a university-based postgraduate program. Another important aspect is the availability of a large enough patient pool for the dentist to generate a sufficient number of implant patients each year. This allows the establishment of a good routine not only for the clinician, but also for ancillary staff members. Clinicians should aim to perform at least one implant surgery per week on average as a requirement to establish this necessary routine. It is also important to have an appropriate infrastructure in the dental office to allow the procedure to be performed well in a hygienic surgical environment.

In addition, the clinician must demonstrate proper judgment of the clinical situation in a given clinical situation. This judgment should provide information not only on the level of difficulty of the planned treatment depending on the patient's risk profile, but also on the clinician's ability to perform the planned procedure. Clinicians must be aware of their own level of clinical competence, and should not attempt procedures beyond their capabilities and experience. A useful tool is the SAC classification (19), which provides the clinician with certain guidelines to classify clinical cases as S (straightforward), A (advanced), or C (complex). From a quality assurance point of view, it seems logical that the more advanced or complex a clinical situation is, the more experienced and skillful the involved clinician(s) and dental technician should be. It is important to recognize that the various indications of implant therapy in the

esthetic zone have all been classified as being either advanced or complex level. In such cases, the treatment is often performed with a team approach having specialized surgical and reconstructive colleagues involved in collaboration with a qualified dental technician.

Preoperative planning: clinical assessment

A careful examination and diagnosis of the clinical situation is required to establish an appropriate treatment plan. While it is not the purpose of this chapter to provide a detailed review of the diagnostic steps required, there are certain conditions that are important for the clinician to be aware of in order to minimize esthetic risk. These conditions, comprising systemic, extraoral and intraoral factors, and patient expectations, form the basis of the esthetic risk assessment (ERA) for implant therapy proposed by Martin *et al.* (20). The key intraoral or local site factors are as follows.

- *Gingival biotype*: Thin gingival biotype situations present with a much higher risk of mucosal recession than thicker gingival biotypes.
- *Shape of tooth or crowns*: In general, replacement of teeth that are more triangular in shape present with higher esthetic risk than teeth with a rectangular outline. Greater challenges are presented to the clinician in closing embrasure spaces and creating narrower cervical contours when replacing triangular teeth.
- *Infection at the implant site*: In dentate sites, the presence of acute infection increases the difficulty of managing the peri-implant soft tissues during the surgical procedure and the risk of complications postoperatively.
- *Bone level at adjacent teeth*: The bone level at proximal surfaces of adjacent teeth dictates the height and form of the implant–tooth papilla after restoration of the implant. Natural teeth that have compromised proximal bone increase the risk of a reduced or absent papilla.
- *Restorative status of neighboring teeth*: When teeth adjacent to the proposed implant site have been crowned, there is an elevated risk of recession occurring postoperatively and exposure of the crown margins after healing.
- *Width of edentulous span*: In general, multiple adjacent missing teeth are a much greater challenge esthetically than single-tooth replacements. The principal challenge is in creating a papilla between two adjacent implants, or between an implant and a pontic (see Chapter 12).
- *Soft-tissue anatomy*: If the pre-existing site presents with soft-tissue deficiencies in a horizontal and/or vertical plane, this increases the difficulty in achieving ideal esthetic outcomes. Adjunctive hard- and soft-tissue graft procedures are often required.
- *Bone anatomy of the alveolar crest*: This factor is closely related to the soft-tissue anatomy. Where there is a significant effect in the bone (in either a dentate or an edentulous site), adjunctive hard-tissue grafting procedures are usually required.

In addition to these general factors, other specific factors should be considered in the diagnostic and treatment planning stages, as detailed below.

The thickness of the facial bone

The crest of the facial bone is critical for the support of the facial mucosa, and thus maintenance of soft-tissue levels in maxillary anterior implants. In a clinical study, Spray *et al.* (21) demonstrated that if the facial bone was at least 1.8 mm thick at the time of implant placement, then minimal loss of crestal bone height was observed between first and second stage surgery. When the crestal bone was less than 1.8 mm thick, vertical resorption was observed, in some cases exceeding 3 mm from the shoulder of the implant. The clinician must therefore assess the dimension of the ridge to ensure that 2 mm of facial bone thickness can be maintained at the time of implant placement. If the facial bone is anticipated to be less than 2 mm at the time of implant placement, a simultaneous bone augmentation procedure to increase the thickness of the bone should be planned (Fig. 8.14a–e). Bone grafts with low substitution rates should be chosen, combined with submerged or semi-submerged healing.

In immediate implant sites, a similar 2 mm dimension must also be maintained. In a clinical study of immediate implants, Chen *et al.* (12) found that when the distance from implant shoulder to the internal surface of the facial socket wall was less than 2 mm, a significant association with recession of the mucosa was observed. This clinical finding is corroborated by an experimental study in a dog model, which demonstrated that the closer the implant is placed to the facial bone of an extraction socket, the higher the risk of crestal resorption and occurrence of a dehiscence of the facial bone (22).

The contour of the ridge

In the anterior maxilla, resorption of the alveolar ridge will often result in a concavity in the facial bone. Although the bone may have sufficient thickness orofacially, there is a risk that the clinician may inadvertently place the implant in an incorrect axial plane, resulting in the implant being inclined too far facially (Fig. 8.15a, b). This is a situation often encountered in single-tooth lateral incisor sites, particularly if the permanent tooth is congenitally missing. The clinician must assess this carefully,

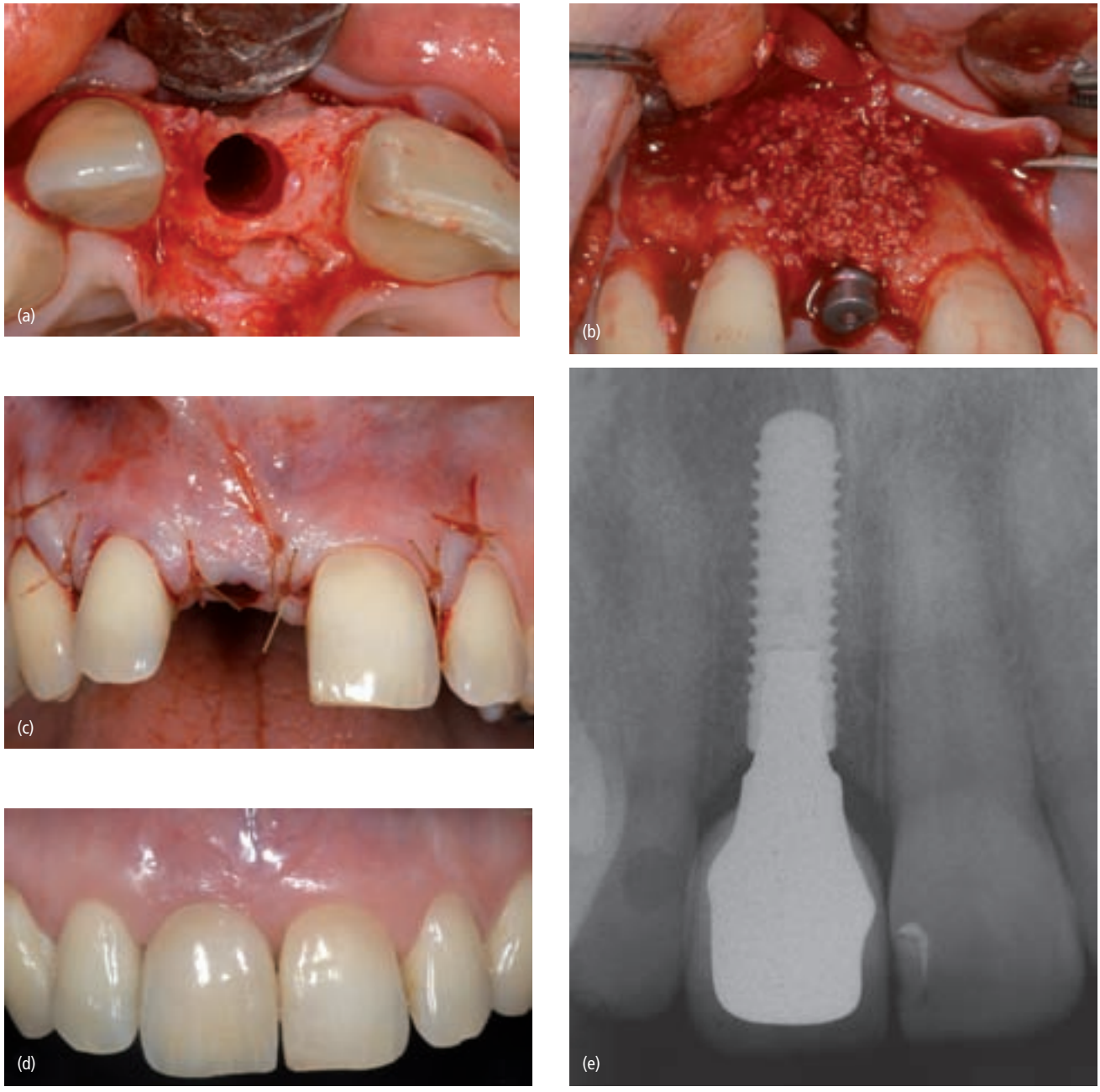


Fig. 8.14 (a) Occlusal intraoperative view after preparation of the osteotomy in an upper right central incisor site. The facial bone wall is thin. (b) Deproteinized bovine bone mineral has been grafted to the facial aspect of the ridge to augment the thickness of the bone, especially at the neck of the implant. (c) The facial flap has been advanced to facilitate semi-submerged healing. (d) The completed implant-supported crown replacing the upper right central incisor. (e) Radiograph of the implant and restoration in the upper right central incisor site.

and determine the risk of a fenestration of the facial bone occurring when the implant is placed into the correct axial position. Care must be taken at the time of implant placement to ensure that the end of the implant does deflect facially through the fenestration. Wide surgical exposure of the site is therefore essential in these clinical situations. If there is a potential for the axial discrepancy to be too great, then a staged bone graft and implant procedure is recommended.

The nasopalatine canal

The location and size of the nasopalatine canal should be carefully assessed preoperatively. The location of the canal will usually influence the mesiodistal position of the implant in an edentulous central incisor site, risking the implant being placed too close to the lateral incisor. Proximity to the lateral incisor may result in loss of the papilla on the mesial aspect of this tooth (Fig. 8.4).

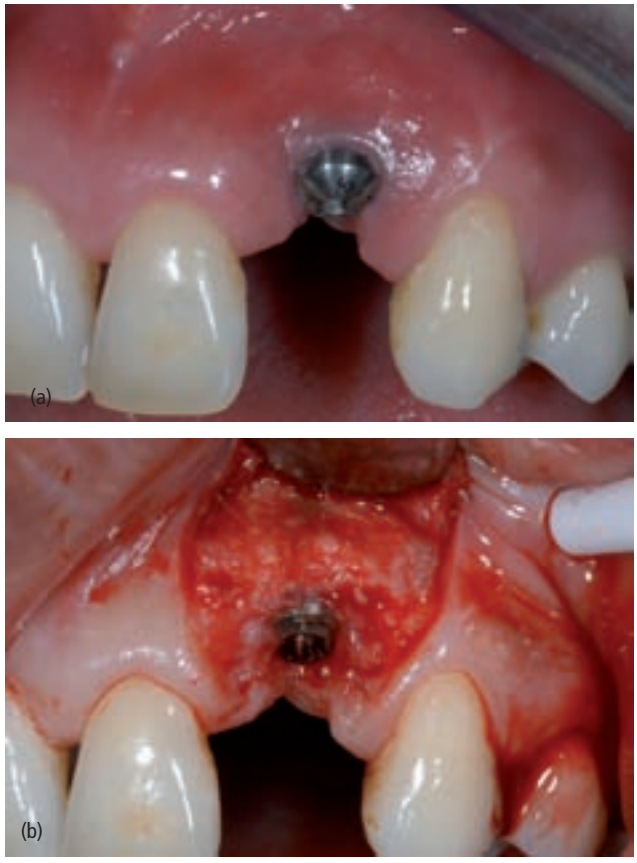


Fig. 8.15 (a) This implant has been placed with a significant facial inclination. Recession of the mucosa was evident even before restoration of the implant. (b) Following flap reflection, the implant was found to be completely contained within the alveolar bone. However, a deep concavity on the facial aspect was clearly evident. This concavity caused the implant to be placed in an incorrect axial plane.

Extraction sites

Caution should be exercised when considering immediate implant placement as a treatment approach. In a recent review, it was noted that immediate implant placement was associated with a high incidence of mucosal recession of 1 mm or more ($n = 8$ studies; range 8–40.5%; median 21.4%) in relation to the contralateral teeth (23). The authors noted that the risk of mucosal recession increased with thin tissue biotypes, extraction sites with damage to the facial socket wall, and facial malposition of the implants within the extraction sockets. Thus, clinicians need to exercise proper judgment and skill when carrying out immediate implant placement. As previously discussed, implants should not be placed too close to the facial socket wall, and should preferably be placed with a distance of 2 mm from the facial extent of the shoulder to the internal surface of the facial socket wall (Fig. 8.16). The peri-implant defect should be grafted with a material that has a low substitution rate to reduce the degree of horizontal resorption of the facial bone (12).

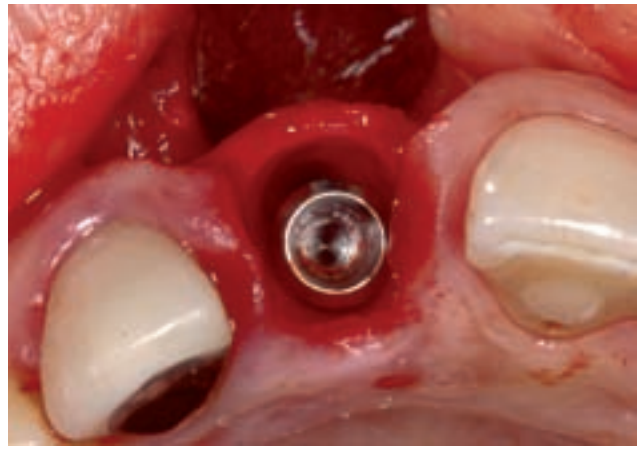


Fig. 8.16 Occlusal view of an implant correctly positioned into an extraction socket of an upper central incisor. A space of 2 mm has been maintained between the implant and the internal surface of the facial bone wall.

A particular risk is in individuals presenting with angle class 2 division 2 occlusions, where the upper anterior teeth are retroclined. In these clinical situations, it is difficult to place the implant in a correct axial position. There is a risk of perforation of the facial socket wall when preparing the osteotomy.

In the presence of a thin tissue biotype, and thin and/or damaged facial bone, a safer approach would be to extract the tooth first and delay implant placement by about 8 weeks (23). This "early implant placement" approach allows healing and an increase in the soft-tissue volume to take place, which in turn facilitates management of the surgical flap and maintenance of an adequate thickness of mucosa on the facial aspect of the implant (Fig. 8.17a–e). A recent retrospective study with 45 implants using early placement after extraction demonstrated a low incidence of recession after 2–4 years of follow-up (24). In a prospective study of early implant placement after extraction, the same authors reported a low incidence of recession, with only one out of 20 sites (5%) exhibiting a recession (25).

Preoperative planning: radiographic assessment

Computed tomography (CT) is widely used as a preoperative diagnostic tool in implant dentistry today. Conventional CT scanners use a linear fan beam to provide images of the bone structures. More recently, cone beam computed tomography (CBCT) scanners using cone-shaped X-ray beams have been introduced into dentistry. CBCT scanners use a square two-dimensional array of detectors to capture the cone-shaped beam. Rather than a set of consecutive slices (as in conventional CT scanning), CBCT scanners produce a volume of data which is then reformatted using reconstruction computer software. The advent of CBCT has further aided the use of this technology in dentistry owing to the compact

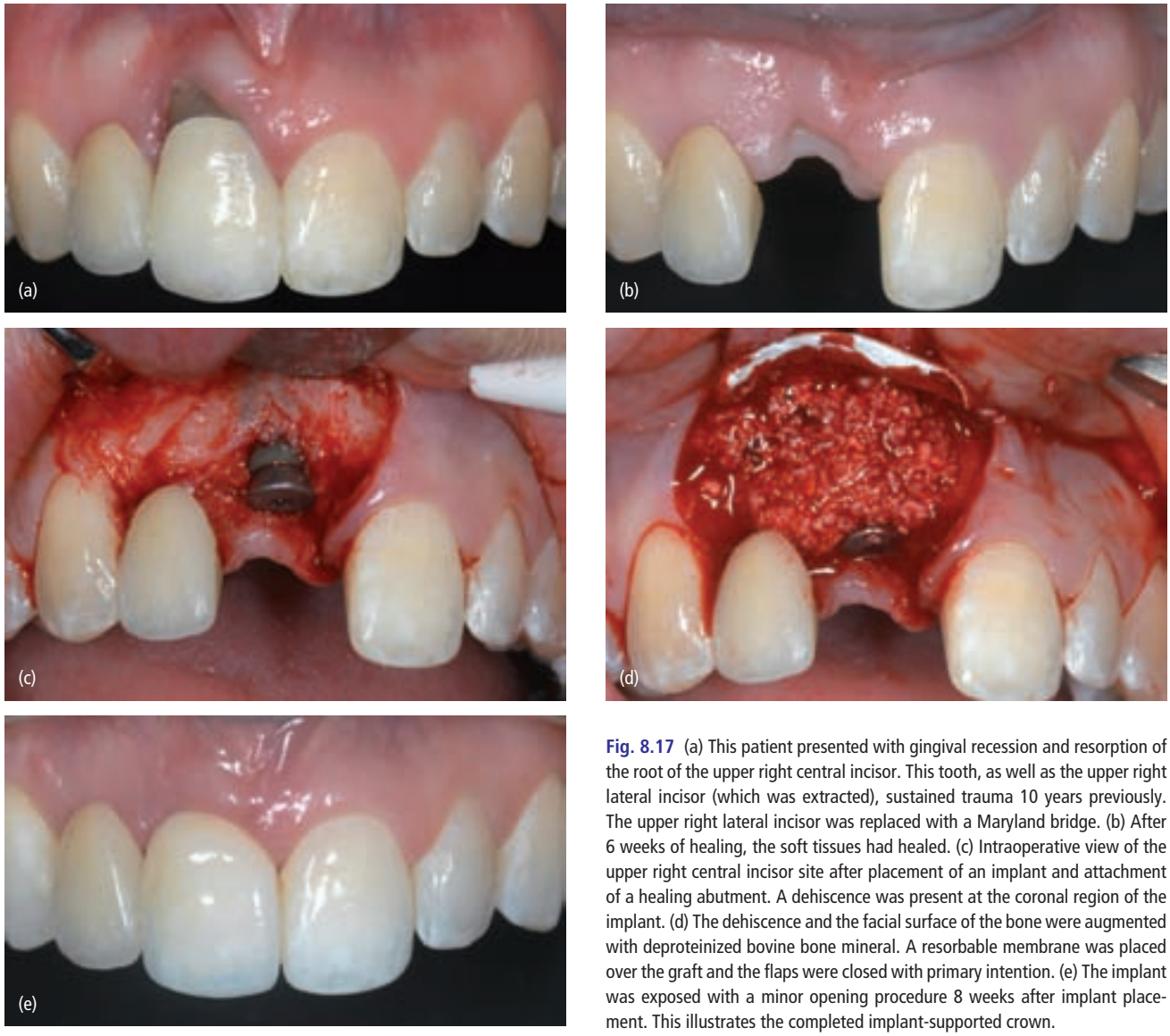


Fig. 8.17 (a) This patient presented with gingival recession and resorption of the root of the upper right central incisor. This tooth, as well as the upper right lateral incisor (which was extracted), sustained trauma 10 years previously. The upper right lateral incisor was replaced with a Maryland bridge. (b) After 6 weeks of healing, the soft tissues had healed. (c) Intraoperative view of the upper right central incisor site after placement of an implant and attachment of a healing abutment. A dehiscence was present at the coronal region of the implant. (d) The dehiscence and the facial surface of the bone were augmented with deproteinized bovine bone mineral. A resorbable membrane was placed over the graft and the flaps were closed with primary intention. (e) The implant was exposed with a minor opening procedure 8 weeks after implant placement. This illustrates the completed implant-supported crown.

size of the equipment, the relative reduction in radiation dosage, and the better image quality compared with conventional CT. However, as with all technologic tools, CBCT scans can be used inappropriately. The relatively low radiation dosage does not justify the indiscriminate use of the technology. The clinician therefore needs to apply this tool effectively in clinical practice.

In edentulous sites, the preoperative volume and morphology of the bony site are evaluated effectively with CT scanning. However, the axial orientation of the alveolar ridge needs to be assessed in relation to the planned orientation of the implant. In single-tooth sites, the proper axial orientation of the implant can usually be assessed by relating axial reformatted images of the site to "ghost images" of the adjacent teeth, as illustrated in Fig. 8.18. This is not so readily achieved in multiple tooth sites. In these situations, it is usually necessary for radiographic stents to be incorporated into the scans to allow the clinician to visualize the relative axes of the alveolar bone and desired implant positions.

In a dentate site, preoperative CT scans are very useful if the implant is to be placed at the time of extraction. Provided the tooth to be extracted is in the correct axial position, the desired orientation of the implant and the availability of bone on the palatal aspect of the socket can be assessed (Fig. 8.19). If early placement is planned, then pre-extraction CT scans are less useful as the condition after extraction may change with modeling of the bone. CT scans taken after extraction and just before implant placement will not usually show the crestal region of the healing socket owing to poor mineralization at this stage. Therefore, an accurate assessment of available bone height is not always possible. However, scans taken postextraction will show the orofacial bone width at the proximal regions of adjacent teeth. These dimensions will provide the clinician with a guide as to

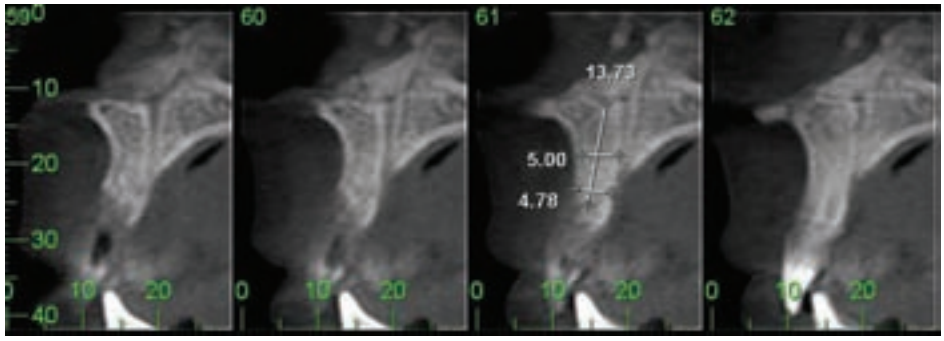


Fig. 8.18 Reformatted cone beam computed tomographic views of the site of a missing upper right central incisor site (slices 59 and 60) adjacent to the upper left central incisor (slices 61 and 62). By observing the "ghost image" of the left incisor over the right incisor ridge, it is possible to determine that there is sufficient bone volume to place an implant in the correct axial position. However, a fenestration of the facial bone could occur at the time of surgery.

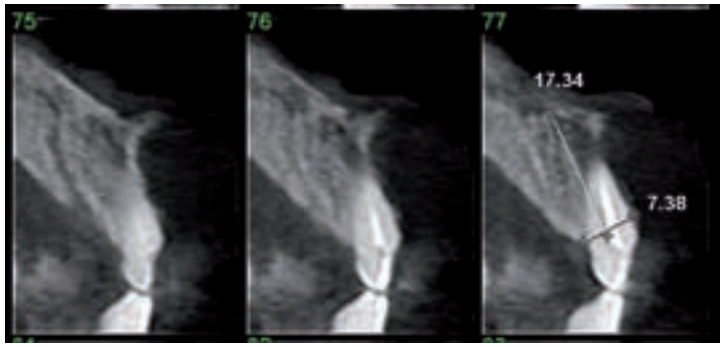


Fig. 8.19 Reformatted cone beam computed tomographic views of an upper left central incisor showing sufficient bone volume on the palatal aspect of the socket to allow an implant to be placed at the time of extraction.

whether the implant can be placed within the alveolar housing, and whether anticipated bone defects on the facial surface of the implant have a sufficient number of bone walls to allow simultaneous bone augmentation procedures to be performed.

Use of surgical stents

To achieve a correctly positioned implant position, a surgical stent can be useful. However, owing to the additional cost to patients, they may not have to be used in every patient. Experienced implant surgeons might not use them in single-tooth gaps, since adjacent teeth provide sufficient landmarks for the clinician to orient the implant bed preparation sufficiently. The incisal edge, the facial point of emergence, and the CEJ of adjacent teeth provide these important anatomic landmarks. In sites with multiple missing teeth, the use of surgical stents is highly recommended. The stent is based on a wax-up to determine the future shape and volume of the implant-borne restoration (Fig. 8.20a). Many clinicians clearly prefer the translucent vacuum-formed (suck-down) stent, which outlines the future facial margin of the implant crowns and the incisal edges, but without a drilling guide embedded in the stent. In this design, the stent is open on the palatal aspect (Fig. 8.20b), giving the surgeon a certain freedom with the various drills used during surgery. This type of stent eliminates the risk that mounted sleeves are incorrectly positioned owing to errors in the technical laboratory, which potentially may lead to malpositioned implants. With the help of such surgical stents, which can be easily mounted and removed during surgery, a correct 3D implant positioning is facilitated.

In the mesiodistal direction, the implant shoulder needs to be at least 1 mm distant from adjacent root surfaces. In esthetic sites, it is recommended to use modern implant types providing a platform switching concept, since they have been reported to result in less bone resorption than traditional Brånemark-type implants or tissue-level implants. This concept was introduced by Lazzara in 2006 (26). Meanwhile, several clinical studies have shown that implants with such an abutment offset concept show significantly less bone resorption during healing and the initial bone modeling phase (25, 27, 28). These implants can theoretically be placed slightly closer to adjacent root surfaces (Fig. 8.20c), since they do not cause the typical development of a bone saucer. The correct position in orofacial direction does not differ between tissue-level and bone-level implants. The implants are positioned about 1.5 mm palatally to the theoretical point of emergence (Fig. 8.20e).

In the coronoapical position, it has been recommended to position tissue-level implants about 2 mm apical to the future mucosal margin of the implant crowns (8). This corresponds to approximately 1 mm apical to the CEJ of the contralateral tooth, if the tooth has a non-compromised periodontal condition (Fig. 8.2b). For bone-level implants with a platform switching concept, this distance differs slightly. It is recommended to place these implants with their platform about 3 mm apical to the future mucosal margin of the implant crown (Fig. 8.20d).

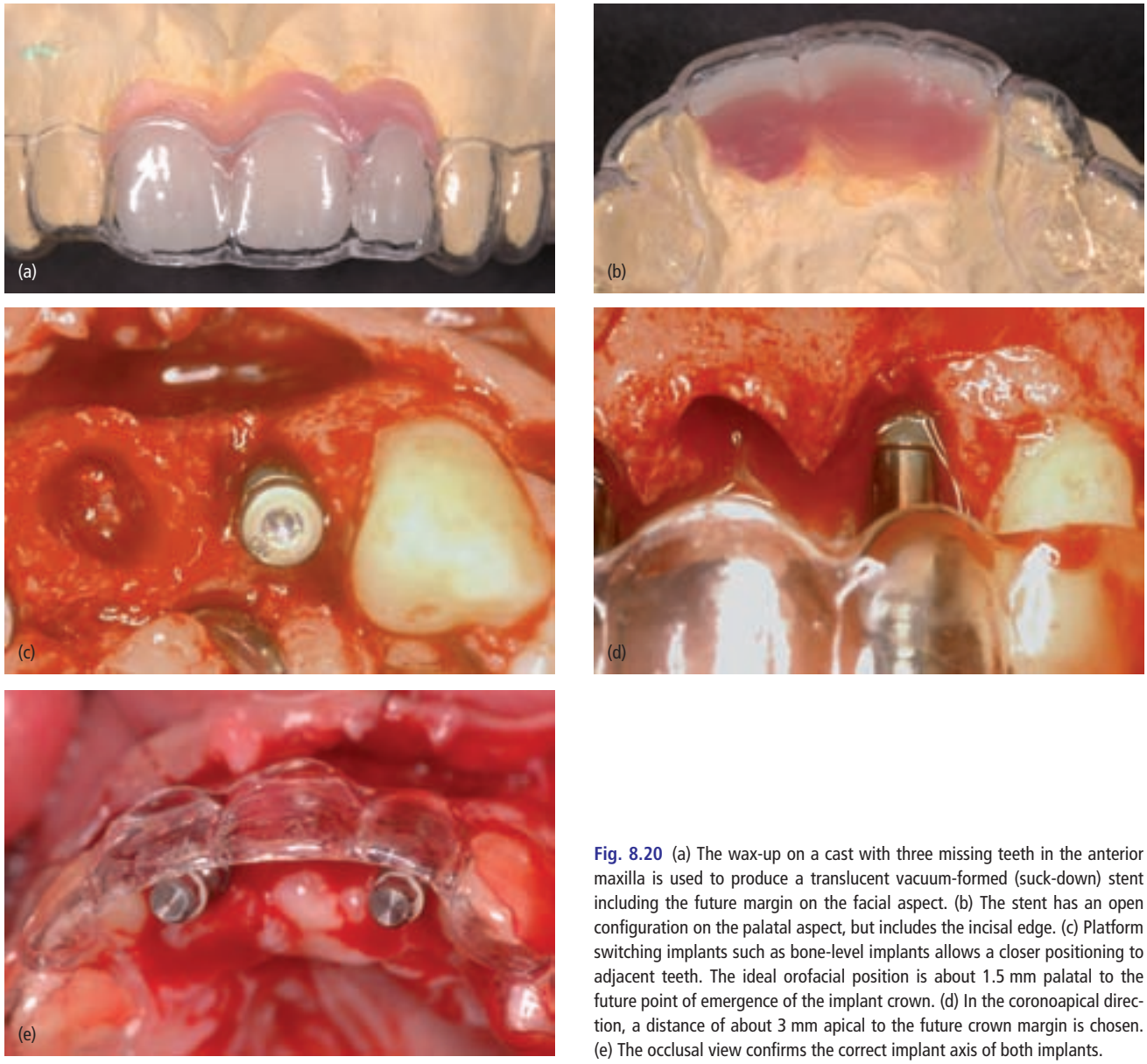


Fig. 8.20 (a) The wax-up on a cast with three missing teeth in the anterior maxilla is used to produce a translucent vacuum-formed (suck-down) stent including the future margin on the facial aspect. (b) The stent has an open configuration on the palatal aspect, but includes the incisal edge. (c) Platform switching implants such as bone-level implants allows a closer positioning to adjacent teeth. The ideal orofacial position is about 1.5 mm palatal to the future point of emergence of the implant crown. (d) In the coronoapical direction, a distance of about 3 mm apical to the future crown margin is chosen. (e) The occlusal view confirms the correct implant axis of both implants.

Following implant insertion, the implant axis should be well positioned to allow transocclusal screw retention of the future restoration without the use of angled abutments (Fig. 8.20e).

Potential of computer-assisted implant surgery

There has been a great deal of interest in computer technology in planning and carrying out implant surgery. These computer-assisted techniques may be divided into static template-based guidance systems and dynamic navigation systems. Both systems use data obtained from CT scans to reconstruct the bone in the planned implant sites. With static template-based guidance systems, a surgical template is constructed from a virtual plan of the implant sites using computer software. The template is then positioned in the patient's mouth and used to guide the surgeon in placing the implants. A limitation of these computer-generated guides is that the location of the implants cannot be altered, unless the template is dispensed with and drilling is performed freehand. In contrast, dynamic navigation systems use infrared cameras to detect the position of the patient and surgical handpiece in real time. The system allows the implants to be placed according to a predetermined plan, but also allows the plan to be altered in real time should the need arise.

In a recent systematic review, Jung *et al.* (29) determined by meta-analysis of 19 preclinical and clinical studies that there was a mean error of 0.74 mm (with a maximum of 4.5 mm) at the entry point and 0.85 mm (with a maximum of 7.1 mm) at the apex of the osteotomy.

Further research is clearly required to improve the accuracy of these techniques before they can be widely used in clinical practice, particularly in situations of reduced bone volume or proximity to vital anatomic structures.

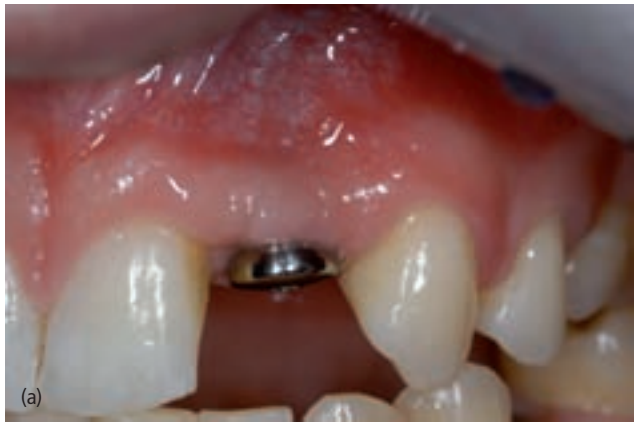
In the management of esthetic areas, computer-assisted techniques may allow the clinician to place implants without flap elevation, provided that there is sufficient bone volume to take into consideration the inherent errors of the system used. Flapless surgery with computer-assisted techniques may be considered in dentate or edentulous sites only when there is no requirement for simultaneous bone augmentation to repair facial bone defects. In the presence of facial bone defects, open-flap procedures are mandatory.

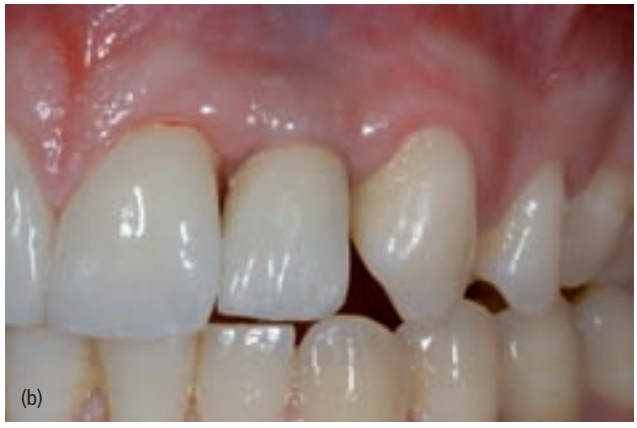
Treatment of esthetic complications due to implant malposition

Successful treatment of esthetic complications due to implant malposition is usually determined by the degree of the malposition and the design of the implant. In presenting treatment options to the patient concerned, great care needs to be taken to discuss the limitations of treatment, and to understate the predictability of the treatments. In the following section, treatment of different malpositions will be discussed, with particular emphasis on the limitations of treatment presented.

Reducing the diameter of the implant platform

If an implant with an oversized platform has been inappropriately chosen for the site, it is sometimes possible to reduce the diameter of the platform by careful preparation of the implant shoulder. This technique is only possible for tissue-level implant designs (Fig. 8.21a–c). Owing to the design of these implants, it is only possible to reduce the diameter of the shoulder by less than 0.5 mm proximally. Therefore, the possibility of reducing the mesiodistal dimension of the shoulder is somewhat limited.





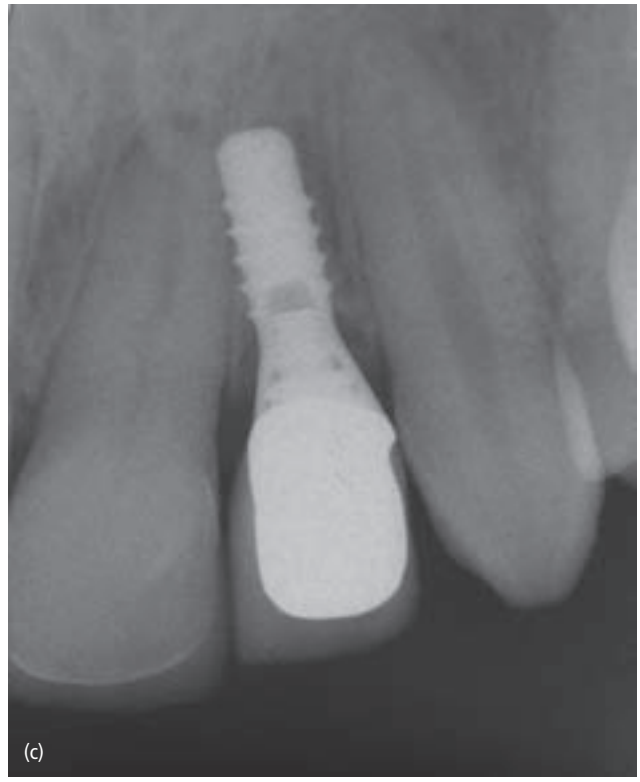


Fig. 8.21 (a) An implant with a restorative platform that was too large for the space has been placed in the upper left lateral incisor site (site 10). Note the proximity of the implant to the adjacent teeth and subsequent flattening of the papillae. The implant also has a coronoapical malposition, and has been inserted too superficially. (b) The tissue-level design of the implant in site 10 allowed reduction of the implant shoulder on the proximal and facial surfaces. The final crown is in place. Note the blunting of the papillae. (c) Radiograph of the final crown in position, after reduction of the implant shoulder.

Soft-tissue grafting

The main esthetic complications that result from implant malposition are blunting or loss of the papillae (often involving the adjacent natural tooth), or recession of the facial marginal mucosa. In practical terms, loss of the papillae is generally irreversible and cannot be corrected in a predictable way. In contrast, recession of the facial marginal mucosa may, in certain situations, be correctable with soft-tissue grafting.

Two approaches may be used to correct recession of the facial marginal mucosa with soft-tissue grafts. In the first approach, connective tissue is grafted to the facial surface of the implant with the crown *in situ* (Fig. 8.22a–c). The technique is similar to that of grafting for root coverage. Following reflection of a split-thickness flap, a connective tissue graft harvested from the palate is secured to the cervical region of the implant and abutment with sling sutures. The facial flap may be coronally advanced in an attempt to cover the graft. The flap is secured in position with sutures. The advantages of this approach are as follows:

- The crown does not need to be removed. This is an advantage particularly when the crown has been cemented onto the abutment.
- An interim removal prosthesis does not need to be worn during the treatment process.

The disadvantage of this approach is that the predictability of achieving mucosal coverage has been shown to be limited. In a recent prospective case series, ten patients with a mucosal recession at a single-implant site were treated with a combination of connective tissue grafts and coronally advanced flaps. The implant crown remained in site. After 6 months, no sites exhibited complete coverage of the soft-tissue dehiscence. An average of 66% coverage was obtained from the ten sites treated (30).

The unpredictability of this technique may be attributed to the following:

- As the original crown is left *in situ*, it is generally not possible to alter or flatten the contour of the crown at the cervical region. Alternatively, a provisional crown may be attached to the implant, with the cervical contour flattened or undercontoured to facilitate placement and stabilization of the graft.
- An underlying orofacial malposition of the implant may not always be identifiable at the time of surgery.
- The peri-implant mucosa is relatively avascular and resembles scar tissue. Therefore, the healing potential may not be comparable to the healing observed for connective tissue grafts in the management of root dehiscences.

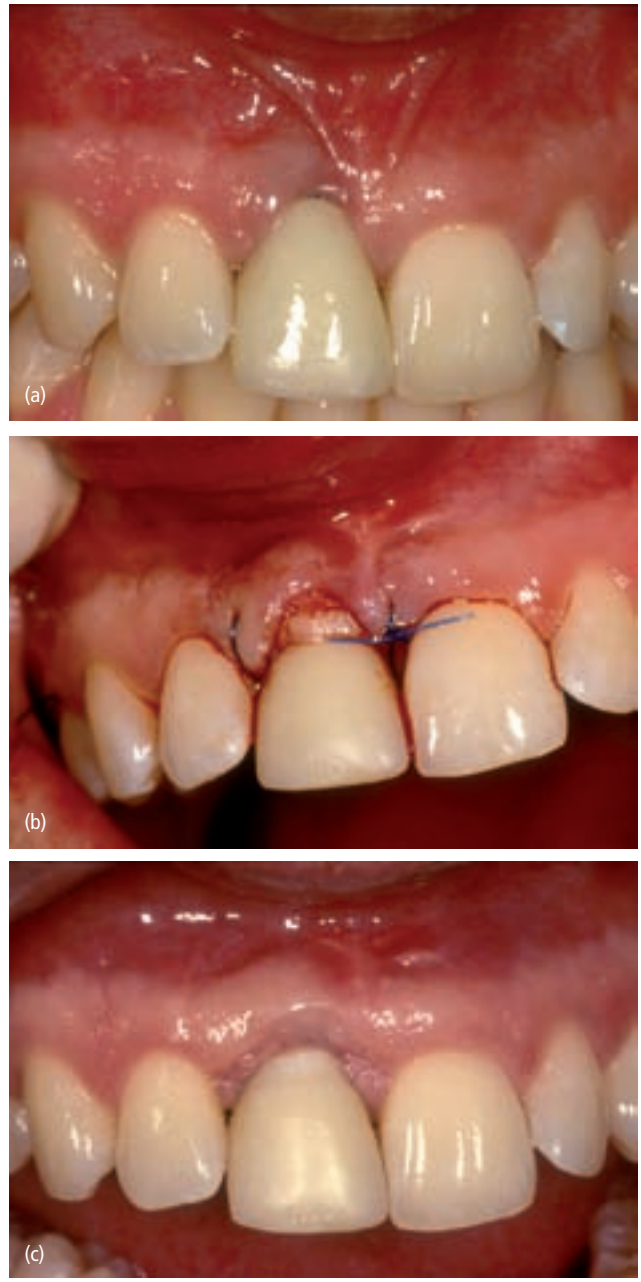


Fig. 8.22 (a) Initial presentation of an implant and crown replacing the upper right central incisor (no. 8). Recession of the mucosa has occurred, exposing the metal collar at the implant shoulder. (b) Before treatment, the definitive crown was removed and a provisional crown with a flattened cervical contour was attached to the implant. Following reflection of a split-thickness flap, a connective tissue graft was positioned over the cervical region of the provisional crown. (c) After 2 months of healing, there was significant thickening of the mucosa. However, only about 50% of the vertical height discrepancy was corrected.

A second approach to grafting with soft tissue is to remove the crown and abutment, and use the soft-tissue graft/flap advancement to submerge partially or completely the implant (Fig. 8.23a–e). Following healing, a

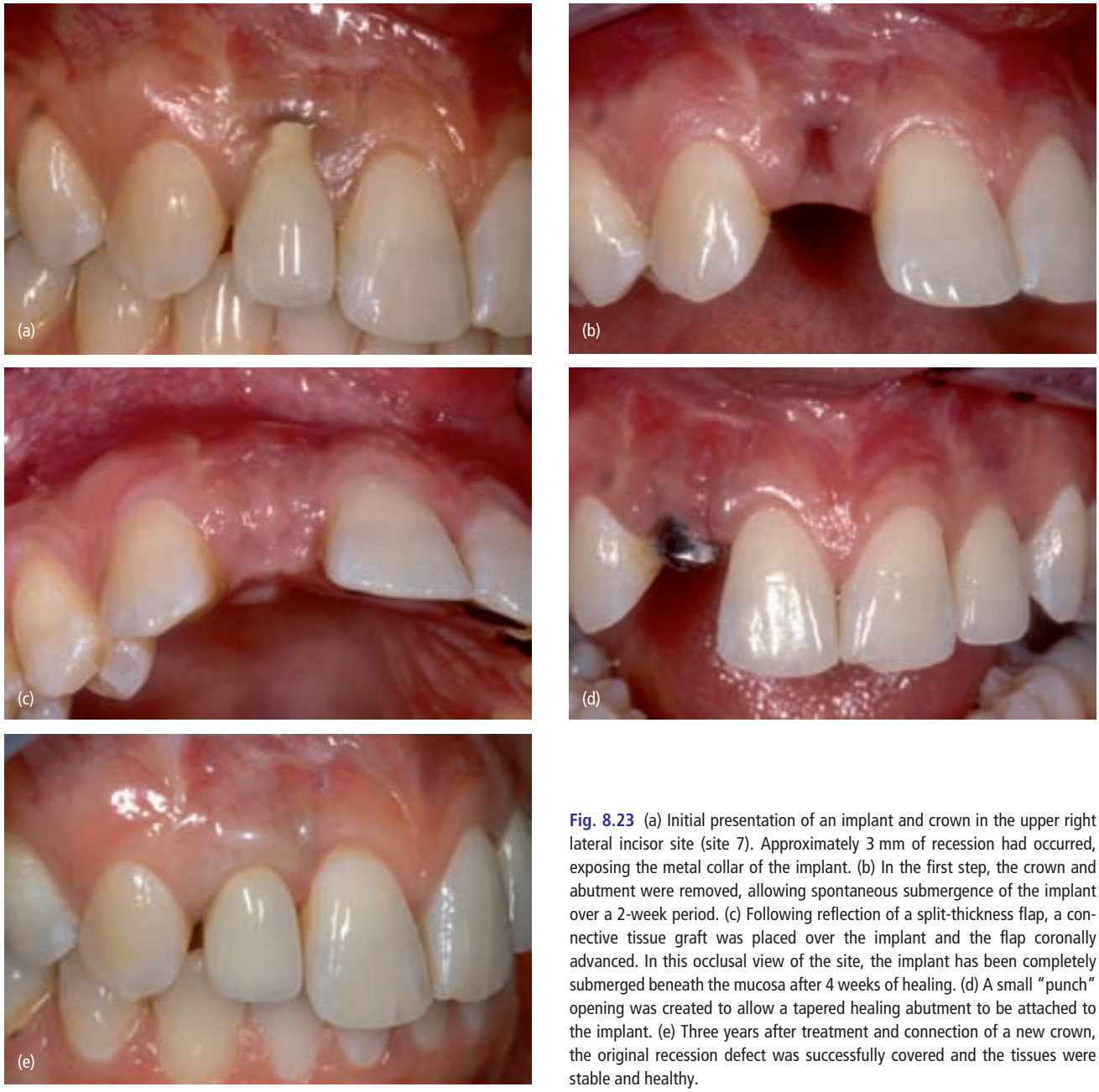


Fig. 8.23 (a) Initial presentation of an implant and crown in the upper right lateral incisor site (site 7). Approximately 3 mm of recession had occurred, exposing the metal collar of the implant. (b) In the first step, the crown and abutment were removed, allowing spontaneous submergence of the implant over a 2-week period. (c) Following reflection of a split-thickness flap, a connective tissue graft was placed over the implant and the flap coronally advanced. In this occlusal view of the site, the implant has been completely submerged beneath the mucosa after 4 weeks of healing. (d) A small "punch" opening was created to allow a tapered healing abutment to be attached to the implant. (e) Three years after treatment and connection of a new crown, the original recession defect was successfully covered and the tissues were stable and healthy.

minor reopening procedure may then be performed for reconnection of the abutment and crown. The advantage of this approach is as follows:

- Provided the implant is in a good 3D position, submergence of the implant with soft-tissue grafts is predictable. This increases the volume of soft tissue that can subsequently be displaced to the facial aspect when reconnecting the abutment and crown.

An orofacial malposition of the implant is readily identified when the crown and abutment have been removed. The clinician may then make a judgment as to whether soft-tissue grafting will be effective or not, and can inform the patient accordingly.

The disadvantage of the procedure is that the crown and abutment must be removed before treatment. If the crown has been cemented into place, this generally involves destroying the crown in the process of removal. The patient must also wear an interim provisional during the treatment process, which may span several months.

It is important to note that the facial malposition of the implant does not have to be too great for there to be a significant effect on the final position of the facial mucosa.

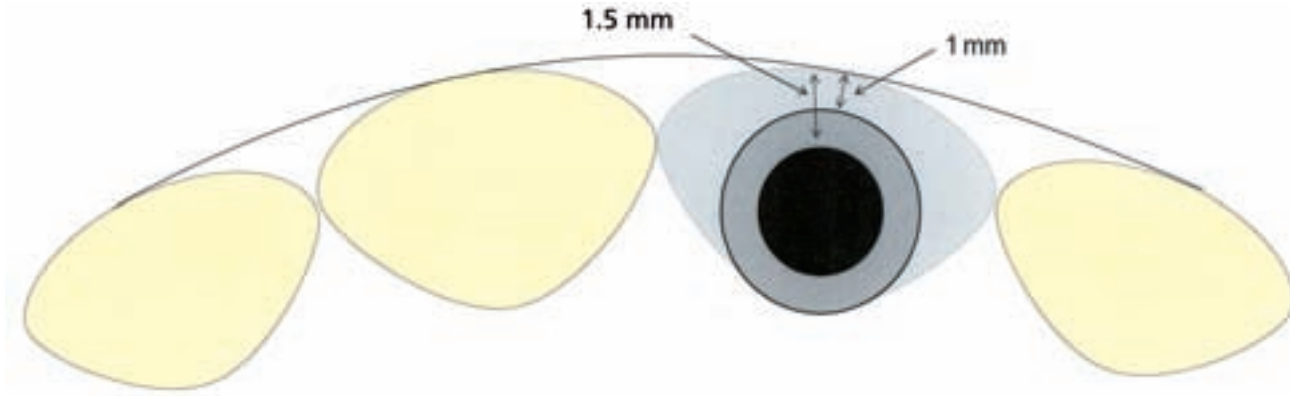
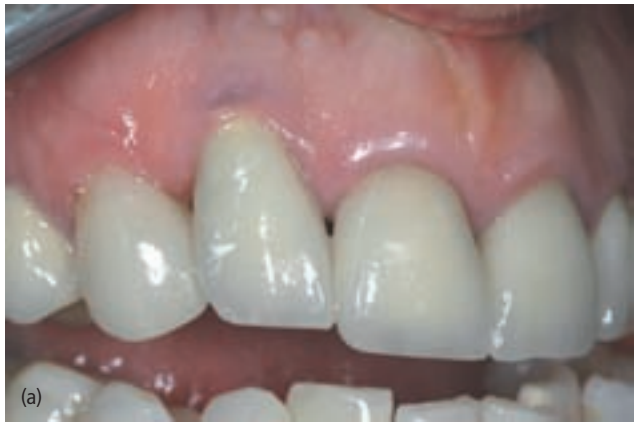


Fig. 8.24 Diagrammatic representation of an implant (black circle) and abutment (gray circle) in a maxillary central incisor space. The distance from the midfacial aspect of the abutment to the facial curvature of the arch at the level of the gingival margin should be at least 1 mm. To achieve this, the distance between the implant shoulder and the facial curvature of the arch at the level of the gingival margin should be about 1.5 mm.

The critical factor is the facial position of the abutment complex in relation to the facial curvature of the dental arch at the level of the gingival margin of the adjacent teeth. As a general rule, there should be at least 1 mm of distance between the most facial aspect of the implant abutment and the ideal curvature of the dental arch. As most abutments extend facially by 0.5 mm when connected to the implant, the implant should be placed with the facial surface about 1.5 mm from the curvature of the arch (Fig. 8.24). An axial malposition of the implant towards the facial aspect only compounds the problem. Therefore, the success of soft-tissue grafting for correction of mucosal recession is limited by the orofacial position and axis of the implant. When the malposition is significant, soft-tissue grafting cannot reverse the recession (Fig. 8.25a–i).

Implant removal and reinsertion of implant in a proper 3D position

When the malposition cannot be corrected with soft-tissue grafting, and the attainment of a good esthetic outcome is essential for the patient, there is usually no alternative but to remove the implant and begin again. Explantation is usually combined with a bone augmentation procedure, followed by the insertion of a new implant into a proper position. For local bone augmentation, the guided bone regeneration (GBR) technique is the preferred surgical procedure, used with either a simultaneous or staged approach. The selected surgical approach mainly depends on the extent and morphology of the bone defect caused by the explantation procedure. Whenever possible, implant placement with simultaneous GBR is used, which is possible in two-wall defects (31), since this eliminates an additional surgical procedure for the patient. Quite often, however, one-wall defects result from explantation procedures, requiring a staged approach with initial ridge augmentation using autogenous block grafts combined with a collagen membrane (32), followed by implant insertion roughly 5–6 months later These treatments are demanding for all involved, the patient and the clinician(s), and often result in somewhat compromised esthetic outcomes (Fig. 8.26a–g).



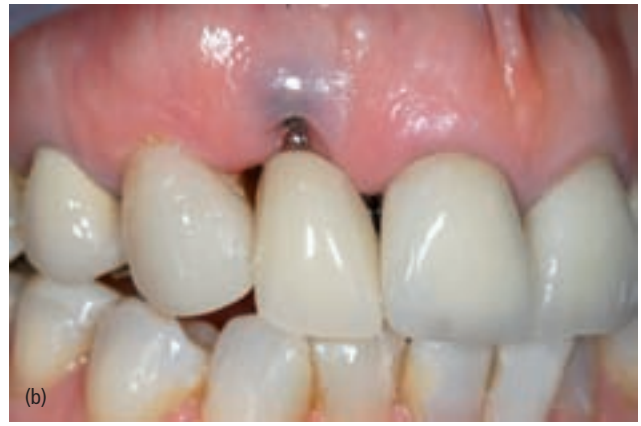
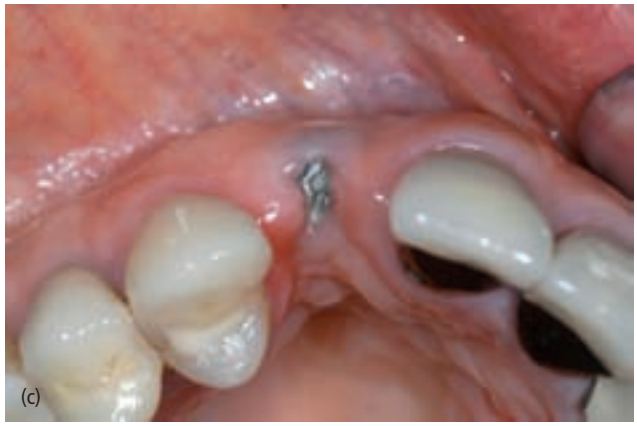
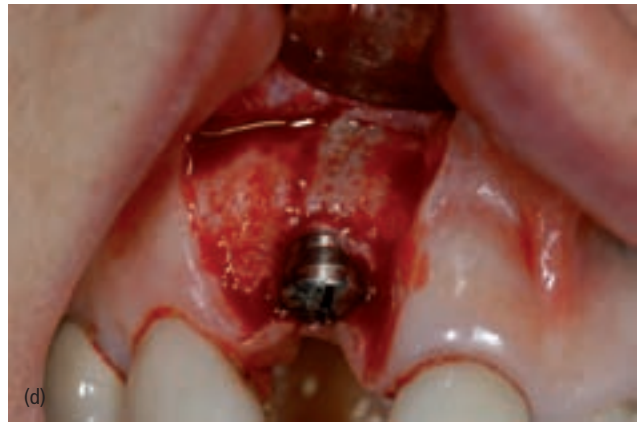
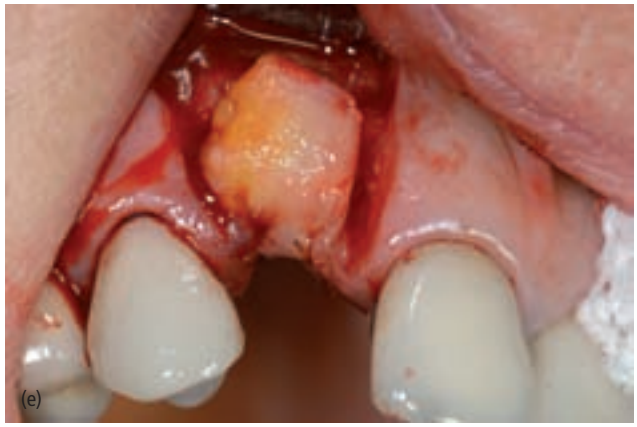
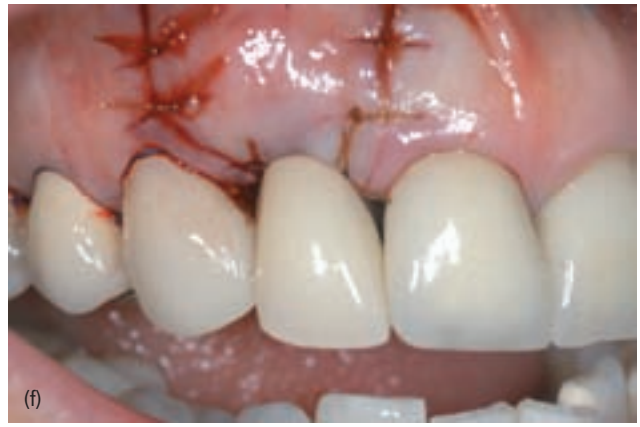


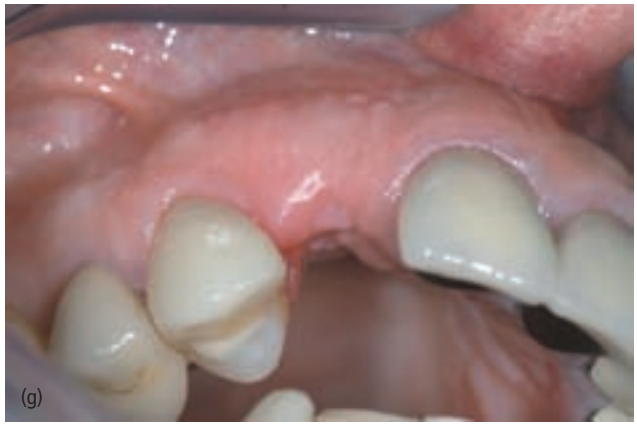
Fig. 8.25 (a) Mucosal recession on the facial aspect of the implant in the upper right lateral incisor site (7). The implant has been placed in a facial malposition. (b) This is the clinical situation after removal of the crown and abutment, with a provisional partial denture in place. The partial denture, having been adjusted to the correct length, highlights the vertical soft-tissue discrepancy.

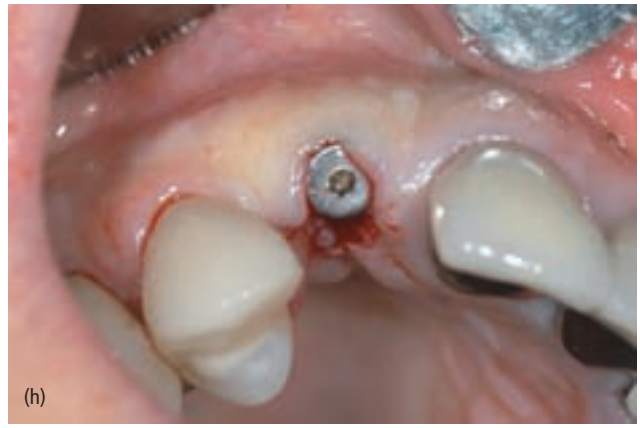












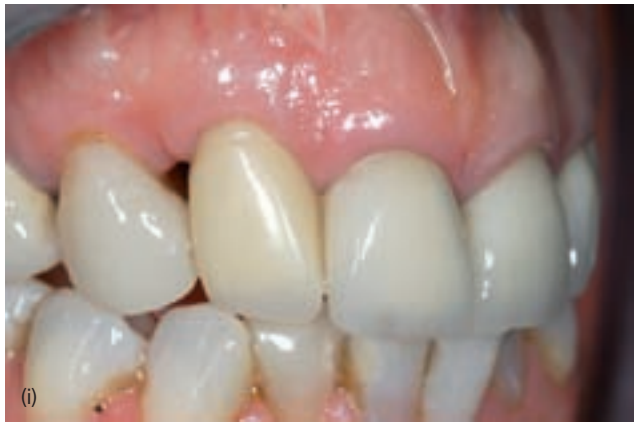
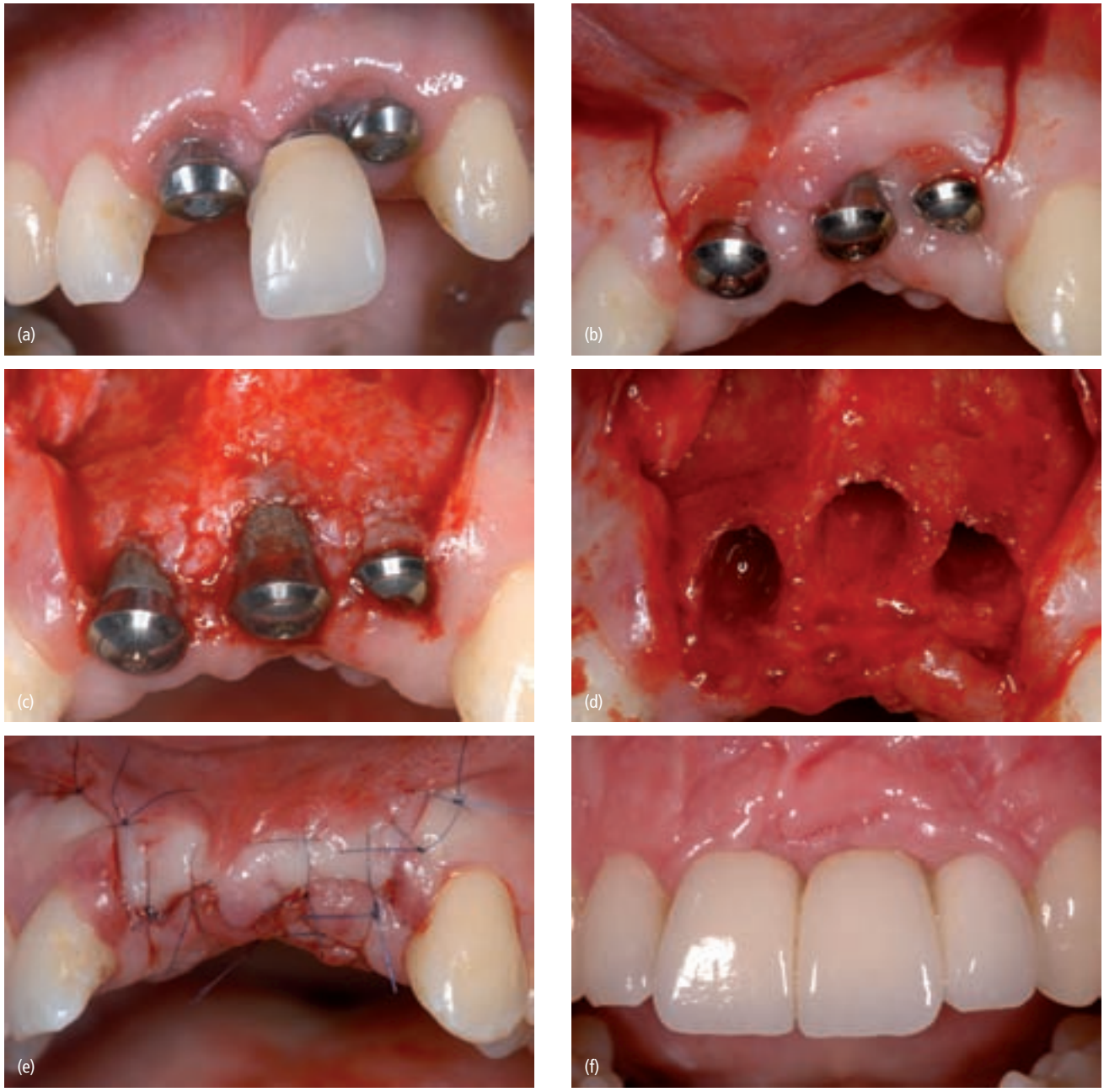


Fig. 8.25 (*cont'd*) (c) Occlusal view of the implant after removal of the crown and abutment, and connection of a healing abutment. The facial malposition of the implant is clearly visible. (d) Following reflection of a buccal full-thickness flap, the crestal bone level is seen to be at the normal position in relation to the implant. (e) A connective tissue graft was harvested from the palate and placed over the facial and occlusal surface of the implant. (f) Facial view of the surgical site after flap closure and insertion of the provisional partial denture. (g) Two months after surgery, the connective tissue graft has fully incorporated into the site and the implant has been submerged. (h) A small opening was made at the crest of the ridge to expose the top of the implant. A milled healing abutment was attached. (i) A provisional crown has been attached to the implant. There has been a reduction in the original height of the recession, but complete reconstruction of the soft-tissue height has not been obtained. Gaining vertical tissue height was limited by the facial malposition of the implant.



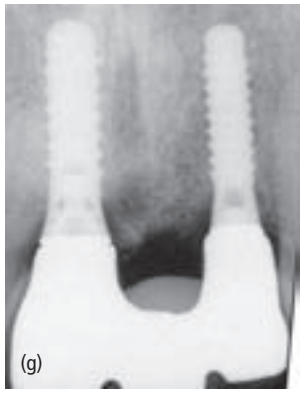


Fig. 8.26 (a) A disaster case in the anterior maxilla with three implants in place. First, only two implants in area 8 and 11 should have been used for an esthetic treatment outcome. Second, implant 8 is inserted in a coronal malposition with an exposed implant shoulder. The removal of all three implants is required. (b) Removal surgery with a small papilla-sparing incision to limit the surgical trauma during the removal process. (c) The extent of the facial bone deficit is clearly visible after elevation of a mucoperiosteal flap. A careful osteotomy will be carried out mainly on the approximal implant surfaces to limit bone removal on the facial aspect. (d) Clinical status after the removal of all three implants. The resulting bone defects were débrided and filled with collagen plugs. (e) The surgery is completed with a primary wound closure to achieve intact soft tissues in the edentulous area. Implant placement with simultaneous guided bone regeneration (GBR) was scheduled 6–8 weeks later. (f) Final treatment outcome 3 years after placement of two implants with simultaneous GBR for localized contour augmentation. In the pontic area, a vertical ridge augmentation was performed with a low-substitution bone filler (deproteinized bovine bone mineral). (g) Radiographic status at the 3-year follow-up examination. The newly placed two implants show stable peri-implant bone crest levels, especially in the pontic area.

Conclusions

In implant dentistry today, patients and clinicians are seeking predictable methods for replacing teeth in the esthetic zone. The esthetic nature of this treatment is associated with strong psychologic and emotional patient-related factors which must be carefully assessed before the commencement of treatment. It is the clinician's responsibility to determine whether the esthetic expectations of the patient can be reasonably achieved with the clinical techniques available. There are many situations in which the presenting clinical situation makes it impossible to reverse hard- and soft-tissue loss, and therefore to provide a prosthetic replacement for the missing tooth or teeth that mimics the original natural dentition. These limitations must be discussed with the patient before treatment commences.

The clinician must also critically assess his or her own ability to provide the treatment to the level that is required to achieve a satisfactory outcome. It should be clear from the discussions in this chapter that minor variations to implant position and soft- and/or hard-tissue augmentation procedures may have significant effects on esthetic outcomes. The dental tissues are unforgiving when it comes to achieving ideal esthetic results with dental implants, and seemingly minor errors in judgment and execution of treatment can have profound implications. When errors take place and esthetic outcomes are less than ideal, therapeutic procedures to correct these are limited at this time. Therefore, the most effective principle for managing esthetic problems with implants is to ensure that steps are taken to avoid them in the first place.

Take-home hints

- Ensure that the patient understands the esthetic implications of treatment and risks involved. Pre-existing hard- and soft-tissue deficiencies often preclude achieving ideal esthetic outcomes.
- Carefully assess the hard- and soft-tissue dimensions of the site in relation to the planned implant position. The aim is to maintain 2 mm of thickness of the facial bone. If necessary, augment the site first to optimize the hard- and soft-tissue conditions before placing the implant.
- The clinician should not attempt treatment in the esthetic zone if the procedures required are beyond his or her clinical skill and experience.
- Select an implant with the correct restorative platform in relation to the dimensions of the tooth to be replaced.
- Ensure that the implant is placed in the correct restoratively determined 3D position. The implant should be placed:
  - in the mesiodistal plane, at least 1.5 mm away from the roots of adjacent teeth
  - in the apicocoronal plane, between 2 and 3 mm (depending on the design of the implant) apical to the anticipated mucosal margin of the implant restoration
  - in the orofacial plane, at about 1.5 mm orally to the facial curvature of the arch at the level of the gingival margin.
- A surgical guide stent should be considered if it is anticipated that there may be difficulty in correctly positioning the implant. Surgical stents are highly recommended in sites with multiple missing teeth.
- If at the time of surgery there are any doubts about the position of the implant, it is better to abort the procedure than to place the implant into an incorrect position. Reassess the site, and determine the reason for the incorrect position. If necessary, augment the site to optimize the hard- and soft-tissue conditions before returning to place the implant(s).
- Esthetic complications due to implant malposition are unforgiving and difficult to treat, and it is recommended that the clinician always err on the side of caution.

References

1. Buser D, Chen ST. Factors influencing treatment outcomes in post-extraction implants. In: Buser D, Wismeijer D, Belser UC, eds. *ITI treatment guide. Vol 3, Implant placement in post-extraction sites. Treatment options.* Berlin: Quintessence, 2008: 18–28.
2. Parel SM, Sullivan DY. *Esthetics and osseointegration*. University of Texas Health Science, 1989.
3. Berglundh T, Lindhe J. Dimension of the periimplant mucosa. Biological width revisited. *J Clin Periodontol* 1996; **23**: 971–3.
4. Cochran DL, Hermann JS, Schenk RK, Higginbottom FL, Buser D. Biologic width around titanium implants. A histometric analysis of the implanto-gingival junction around unloaded and loaded nonsubmerged implants in the canine mandible. *J Periodontol* 1997; **68**: 186–98.
5. Kan JY, Rungcharassaeng K, Umezu K, Kois JC. Dimensions of peri-implant mucosa: an evaluation of maxillary anterior single implants in humans. *J Periodontol* 2003; **74**: 557–62.
6. Garber DA, Belser UC. Restoration-driven implant placement with restoration-generated site development. *Comp Contin Educ Dent* 1995; **16**: 796, 798–802, 804.
7. Belser UC, Bernard JP, Buser D. Implant-supported restorations in the anterior region: prosthetic considerations. *Pract Periodont Aesthet Dent* 1996; **8**: 875–83.

8. Buser D, Martin W, Belser UC. Optimizing esthetics for implant restorations in the anterior maxilla: anatomic and surgical considerations. *Int J Oral Maxillofac Implants* 2004; **19** (Suppl): 43–61.
9. Esposito M, Ekestubbe A, Grondahl K. Radiological evaluation of marginal bone loss at tooth surfaces facing single Brånemark implants. *Clin Oral Implants Res* 1993; **4**: 151–7.
10. Small PN, Tarnow DP. Gingival recession around implants: a 1-year longitudinal prospective study. *Int J Oral Maxillofac Implants* 2000; **15**: 527–32.
11. Chen ST, Darby IB, Adams GG, Reynolds EC. A prospective clinical study of bone augmentation techniques at immediate implants. *Clin Oral Implants Res* 2005; **16**: 176–84.
12. Chen ST, Darby IB, Reynolds EC. A prospective clinical study of non-submerged immediate implants: clinical outcomes and esthetic results. *Clin Oral Implants Res* 2007; **18**: 552–62.
13. Chen ST, Darby I, Reynolds EC, Clement JG. Immediate implant placement post-extraction without flap elevation: a case series. *J Periodontol* 2009; **80**: 163–72.
14. Lindeboom JA, Tjiook Y, Kroon FH. Immediate placement of implants in periapical infected sites: a prospective randomized study in 50 patients. *Oral Surg Oral Med Oral Pathol Endodont* 2006; **101**: 705–10.
15. Kan JYK, Rungcharassaeng K, Sclar A, Lozada JL. Effects of the facial osseous defect morphology on gingival dynamics after immediate tooth replacement and guided bone regeneration: 1-year results. *J Oral Maxillofac Surg* 2007; **65**: 13–19.
16. Evans CJD, Chen ST. Esthetic outcomes of immediate implant placements. *Clin Oral Implants Res* 2008; **19**: 73–80.
17. Garber DA, Salama H, Salama MA. Two-stage versus one-stage – is there really a controversy? *J Periodontol* 2001; **72**: 417–421.
18. Kassolis JD, Baer ML, Reynolds MA. The segmental osteotomy in the management of malposed implants: a case report and literature review. *J Periodontol* 2003; **74**: 529–36.
19. Dawson T, Chen ST. *The SAC classification in implant dentistry.* Berlin: Quintessence, 2009.
20. Martin WC, Morton D, Byser D. Diagnostic factors for esthetic risk assessment. In: Buser D, Belser U, Wismeijer D, eds. *ITI treatment guide*. Vol. 1: *Implant therapy in the esthetic zone – single-tooth replacements.* Berlin: Quintessence, 2007: 11–20.
21. Spray JR, Black CG, Morris HF, Ochi S. The influence of bone thickness on facial marginal bone response: Stage 1 placement through Stage 2 uncovering. *Ann Periodontol* 2000; **5**: 119–28.
22. Araujo MG, Wennstrom JL, Lindhe J. Modeling of the buccal and lingual bone walls of fresh extraction sites following implant installation. *Clin Oral Implants Res* 2006; **17**: 606–14.
23. Chen ST, Buser D. Clinical and esthetic outcomes of implants placed in postextraction sites. *Int J Oral Maxillofac Implants* 2009; **24**: 186–217.
24. Buser D, Bornstein MM, Weber HP, Grütter L, Schmid B, Belser UC. Early implant placement with simultaneous guided bone regeneration following single-tooth extraction in the esthetic zone: a cross-sectional, retrospective study in 45 subjects with a 2- to 4-year follow-up. *J Periodontol* 2008; **79**: 1773–81.
25. Buser D, Halbritter S, Hart C, Bornstein MM, Grütter L, Chappuis V, Belser UC. Early implant placement with simultaneous guided bone regeneration following single-tooth extraction in the esthetic zone: 12-month results of a prospective study with 20 consecutive patients. *J Periodontol* 2009; **80**: 152–62.
26. Lazzara RJ, Porter SS. Platform switching: a new concept in implant dentistry for controlling postrestorative crestal bone levels. *Int J Periodont Restor Dent* 2006; **26**: 9–17.
27. Palmer RM, Palmer PJ, Smith BJ. A 5-year prospective study of Astra single tooth implants. *Clin Oral Implants Res* 2000; **11**: 179–82.
28. Canullo L, Rasperini G. Preservation of peri-implant soft and hard tissues using platform switching of implants placed in immediate extraction sockets: a proof-of-concept study with 12- to 36-month follow-up. *Int J Oral Maxillofac Implants* 2007; **22**: 995–1000.
29. Jung RE, Schneider D, Ganeles J, Wismeijer D, Zwahlen M, Hammerle CHF, Tahmaseb A. Computer technology applications in surgical implant dentistry: a systematic review. *Int J Oral Maxillofac Implants* 2009; **24**: 92–109.
30. Burkhardt R, Joss A, Lang NP. Soft tissue dehiscence coverage around endosseous implants: a prospective cohort study. *Clin Oral Implants Res* 2008; **19**: 451–7.
31. Buser D. Implant placement with simultaneous GBR procedures: selection of biomaterials and surgical principles. In: Buser D, ed. *20 years of guided bone regeneration in implant dentistry*, 2nd ed. Berlin: Quintessence, 2009: 123–52.
32. Von Arx T, Buser D. Horizontal ridge augmentation using autogenous block grafts and the guided bone regeneration technique with collagen membranes: a clinical study with 42 patients. *Clin Oral Implants Res* 2006; **17**: 359–66.

Chapter 9

Prosthodontic complications related to non-optimal dental implant placement

John S. Cavallaro Jr. DDS *and Gary Greenstein* DDS, MS

Introduction

Osseointegration of dental implants is a predictable treatment modality (1–4); however, restorative complications due to non-optimal implant placement do occur (5–8). Undesirable outcomes relating to an implant's location may affect the success and longevity of a prosthetic rehabilitation. These sequelae arise when implants are not optimally placed in one or more geometric planes (e.g. buccolingually, mesiodistally, apicocoronally). Therefore, after implant placement and before selecting a restorative strategy, it should be decided whether it is necessary to address issues pertaining to implant insertion with respect to position, angulation, or depth. This chapter describes concepts to achieve clinically acceptable prosthetic rehabilitations when problems arise owing to non-optimal implant location.

Three-dimensional determinants for correct implant placement

An optimal restoration is facilitated by ideal implant placement. In this regard, three factors need to be considered when inserting an implant: position, angulation, and depth. Prosthetic dilemmas pertaining to these factors will be addressed separately. However, these issues can occur singly or in combination with each other and they can result in difficulty with respect to fabricating an esthetic, functional restoration (Fig. 9.1). Unfortunately, many implant placement issues are not detected until the prosthetic phase of treatment when a transmucosal component is attached to the implant. At that juncture, components that help identify placement issues include transfer copings, guide pins, and interim or definitive abutments.

The etiology of prosthetic complications related to implant placement can often be attributed to lack of attention to detail when developing the treatment plan and failure to use a surgical guide while inserting implants. During the planning phase, appropriate radiographic scans combined with study casts can provide comprehensive information concerning the three-dimensional (3D) anatomy of an implant site (9). In addition, the need for site development before implant placement can be evaluated (10–15). For example, a severe labial concavity in the anterior maxilla may warrant grafting as a separate procedure before implant insertion or the site may be avoided as an implant location. Other problems and solutions that may be encountered during therapy are outlined in Table 9.1.

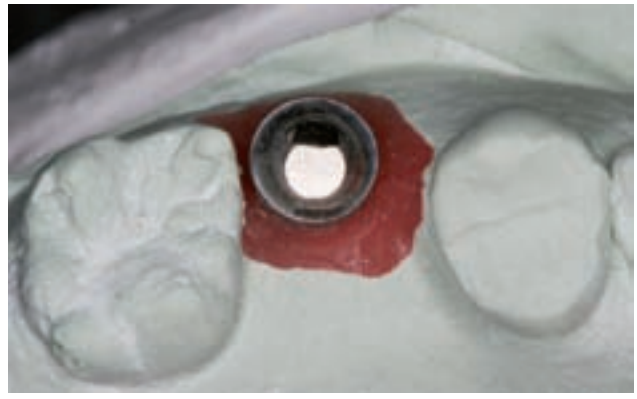


Fig. 9.1 Combination malposition: an implant in the first molar position is placed too far buccally and distally; this will result in unwanted bulkiness on the buccal aspect and an excess of space on the mesial and palatal aspects of the final restoration.

To prevent prosthetic complications, attention to proper implant treatment protocols is required. First, surgical templates should be used as they provide guidance in three planes (buccolingually, mesiodistally, and occlusoapically) for inserting implants (16). Second, an implant surgeon needs to understand the factors necessary to ensure a smooth transition from the surgical to the prosthetic phase of therapy. For example, soft tissue form around an implant is critically important for a successful result (17). Pertinently, before initiation of the restorative phase, the tissue crevice should be managed to permit a transfer coping or an abutment to be seated without difficulty. This can be handled by the implant surgeon using varied-sized healing abutments.

Table 9.1 Implant placement: problems and suggested solutions

Implant placement	Problem	Suggested solution
Lingual undercut posterior mandible	Less than 15° (implant angulation)	Angled abutment – prefabricated or custom
	Greater than 25° (implant angulation)	Use a shorter, wider diameter implant and place more vertically, or graft in order to upright implant placement, avoid site, or fabricate custom abutment to correct severe angulation
Immediate placement into socket	Socket anatomy deflecting twist drill into unintended location	Reshape socket anatomy with a side cutting bur, or delay implant placement
Maxillary sinus, nasal fossa	Minor penetration (<2 mm) into asymptomatic chamber	Use osteotome placement, proceed with optimal implant placement
	Major penetration	Lateral wall sinus augmentation, change site
Difficult visualization posteriorly		Loupes, headlamp, mouth props
Difficult access posteriorly	This should be determined during initial examination	Mouth props, patient sedation, short twist drills
Deep bite	Lingual placement may render implants unrestorable	Implant position centered but angled so that abutment can clear opposing teeth in centric
Wrist pronation causing mesiodistal misangulation		Adequate experience, improve visualization, surgical guide which controls trajectory, use multiple guide pins to help parallel implant osteotomies
Minimal interocclusal space		Select shorter implant and place more apically, occlusal equilibration of opposing teeth, ridge ostectomy

Concomitantly, the soft tissue surrounding an implant should be sculpted to allow for optimal esthetics. The restorative dentist can accomplish reshaping of soft tissue non-surgically by placing appropriate components (e.g. abutment and provisional crown). In general, implant prosthodontic protocols are simplified by optimal implant placement and appropriate soft-tissue management at the time of implant insertion and also before final prosthetic procedures.

Before discussing position, angulation or depth issues, or the prosthetic restoration of malpositioned or misangulated implants, it is important to define the term "running room" (18). Running room is the distance (peri-implant crevicular depth) measured from the implant's prosthetic platform to the free gingival margin. It is the vertical distance to make a transition from the smaller diameter prosthetic platform of an implant to the larger cross-sectional cervical shape of the tooth being restored (Fig. 9.2a, b). For example, the neck of a standard implant is approximately 3.75–4 mm wide, whereas the diameter of a maxillary central incisor at the cementoenamel junction (CEJ) is 7 mm (19). Running room is the distance that is available to create a normal transition (emergence profile) from the implant to the neck of the tooth. For a central incisor the desired running room is approximately 3 mm. In contrast, the width of a lateral incisor at the

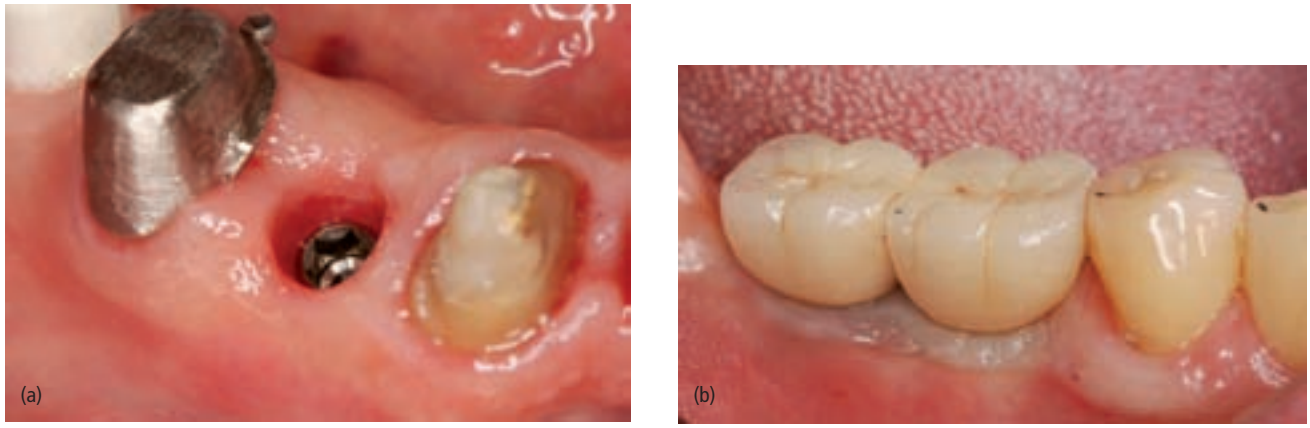


Fig. 9.2 (a) Clinical example of running room (peri-implant crevicular depth or distance); photograph depicting approximately 3 mm running room for a mandibular premolar implant. (b) Restoration in place demonstrating transition from 4 mm diameter implant platform to the larger cervical geometry of a mandibular first molar.

CEJ is 5 mm; therefore the running room (i.e. 2 mm) is less than required for the central incisor.

Positional issues

The position of an implant is defined as the buccolingual and mesiodistal location that the center of the implant occupies within the bone, i.e. the center of the entry point of the implant osteotomy. This is typically created using a round bur or a pilot drill. Implant position is extremely important and the desired location should be determined before fabricating a surgical guide (20). During the presurgical planning phase, prosthetic goals are established using mounted study casts, which permit waxing of ideal restorative contours. A step-by-step procedure for fabrication of a radiologic and/or surgical guide is presented here:

1. Make maxillary and mandibular impressions (two sets) using alginate impression material.
2. Pour impressions in dental stone.
3. Prepare a diagnostic wax-up of intended restorative contours on one set of casts (the other set is to remain unaltered for reference purposes).
4. Duplicate the waxed cast.
5. A radiologic/surgical guide can now be fabricated out of a transparent vacuformed resin ("suck-down") shell, or in the laboratory from processed resin. For the radiologic guide, any radiopaque material (barium sulfate, lead foil, gutta percha, etc.) can be used to generate markers that will be visible on the radiographic imaging. In converting the radiologic guide to a surgical guide, metal tubes or cutaways can be placed in locations identified as implant sites during the radiographic evaluation.
   - *Caveat*: There must be enough teeth or reference points remaining in the patient's mouth to stabilize the guide in the reproducible position desired.

Ideally, an implant's coronal platform should be placed in the center of the future restoration, which it will support.

Buccolingual malposition

Implants positioned too far facially can produce a number of complications, which are often recognized at the start of the prosthetic phase of treatment. Buccally malpositioned implants can jeopardize the labial cortical plate of bone. Bone loss may occur at the time of implant placement or as a result of osseous resorption during the healing phase (Fig. 9.3) (21–26). In general, soft-tissue topography will follow the underlying osseous contour (27). Therefore, injury to the labial plate of bone may have a detrimental effect on the height of the overlying soft tissue and result in mid-buccal recession. In the esthetic zone, this can produce an unattractive result (Fig. 9.4). Furthermore, if the buccal malposition of the implant is severe, it may not be possible to incorporate it within the confines of the prosthesis.

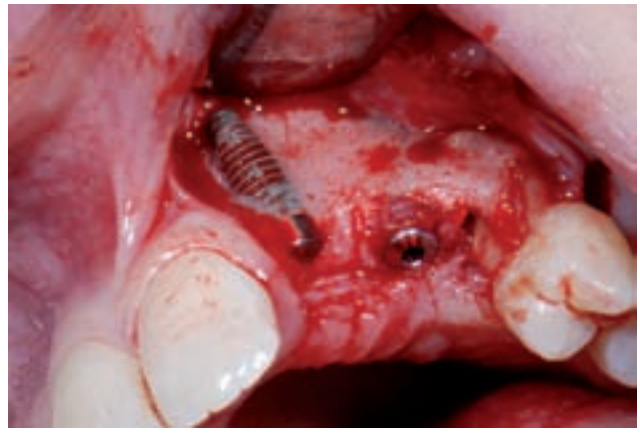


Fig. 9.3 Dehiscence of labial plate of bone caused by implant placed too far buccally.

Implants positioned too far lingually create other problems. In an attempt to restore the crown to its correct position, it may be necessary to create a ridge lap (Fig. 9.5a, b). If it is necessary to position the implant slightly lingual to the ideal position to remain in bone during osteotomy development, then a more apical insertion of the implant will allow additional running room and permit a better emergence profile. This strategy can help avoid or reduce the need for a restoration requiring a ridge lap. Lingual positioning of an anterior implant may also cause a problem if there is a deep overbite. In this latter situation, the occlusal relationship may render a palatally placed implant unrestorable. In addition, a restoration emerging from a palatally placed implant may encroach upon the tongue space, thereby

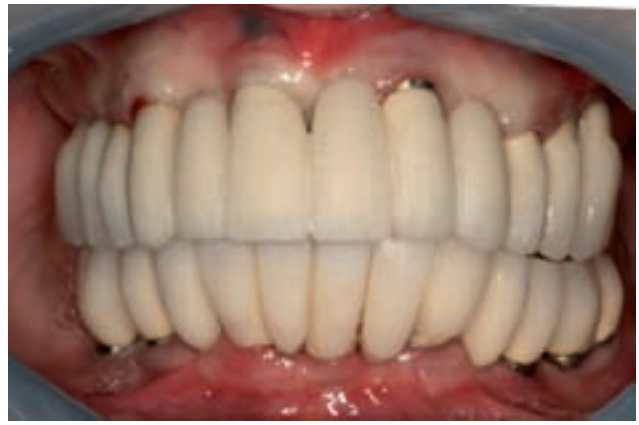


Fig. 9.4 Esthetic restorative complication caused by mid-buccal recession on the maxillary left lateral incisor caused by labial positioning of the implant.

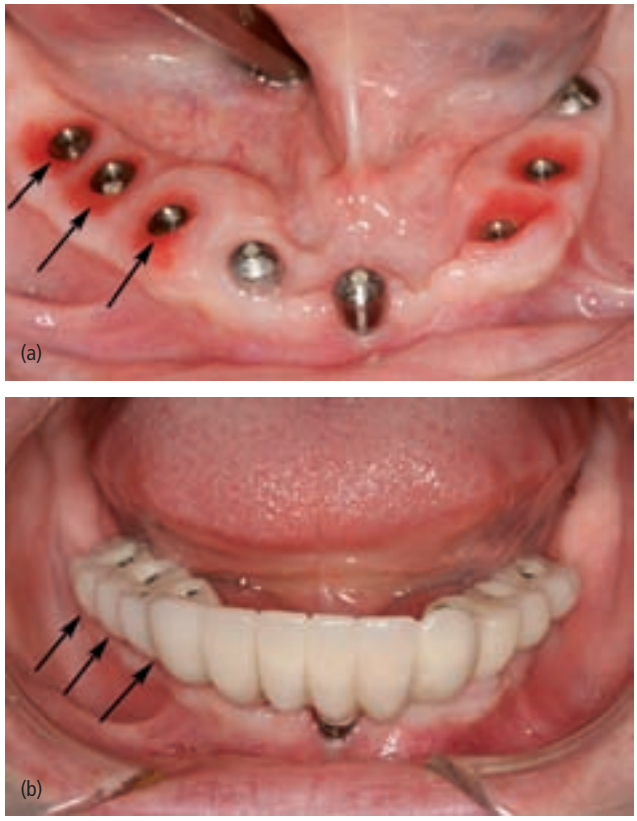


Fig. 9.5 (a) Lingually positioned implants in the mandibular right posterior area. (b) Ridge lapped buccal aspect of the prosthesis resulting from lingually positioned implants. Extra effort must be exerted to clean the buccal undersurface of the restoration.

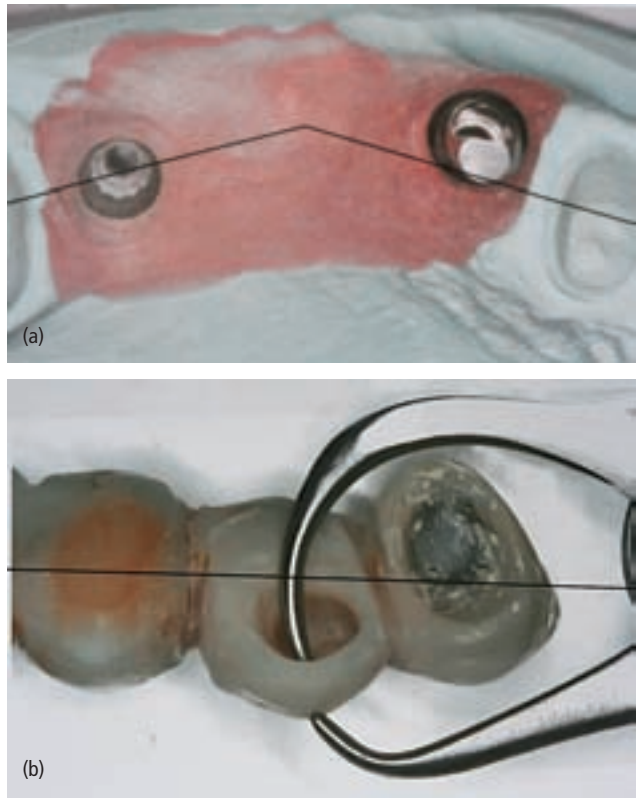


Fig. 9.6 (a) Labially positioned implant in the location of maxillary right first premolar. Note that even with an angulated abutment, the implant is distinctly labial to the optimal location (black line). (b) Modification of the provisional bridge to encompass a labially positioned implant. The measuring gauge is used to evaluate the thickness of the labial resin to be certain that the dimension can be reproduced in a ceramometal restoration.

impeding speech. If this occurs, before final restoration, the malpositioned implant should be incorporated into the provisional prosthesis to assess patient acceptance. Occasionally, the implant will have to remain unrestored or be removed.

When an issue associated with buccolingual positioning of implants is observed before the definitive restorative phase, the provisional restoration should be used to determine whether the implant can be used to support the prosthesis. First, the restoration must be adapted to encompass the malposed implant. This is facilitated by attaching an abutment to the implant and reducing the protruding surface. The provisional bridge should be relined and shaped with a resin thickness that can be reproduced in porcelain (Fig. 9.6a, b) (28). An alternative technique is to fabricate custom abutments that fit within the confines of the intended restoration. Once either of these modifications is found to be acceptable, then treatment can continue. It is prudent to make sure that the patient accepts the provisional result with respect to form and function. Patient concerns regarding the following issues should be addressed: pressure under the lip or a bulky appearance in the case of labial malpositioning; phonetic difficulties and interference with the tongue in the case of lingual malpositioning.

Mesiodistal malposition

Inadvertently, an implant can be placed too close or far from a tooth or adjacent implant, or it can be located within the interproximal space (Fig. 9.7). Usually, it is obvious when a single implant is not centered between adjacent teeth. However, visually judging spacing is more difficult with multiple implants in partially or fully edentulous cases. Recognition of a mesiodistal malposition can be made easier and treated more effectively by using a matrix evaluation methodology (MEM). The term MEM refers to a technique that uses a facial elastomeric matrix to transfer information from the master cast to the mouth, and *vice versa*. For example, if a mandibular fixed implant restoration will be fabricated, an implant-level impression is made and the master implant cast poured and mounted. Three grooves are cut into the border of the cast. Then, the mandibular provisional prosthesis that was in the mouth is transferred to the cast. Next, an elastomeric material (e.g. silicone rubber) is adapted to

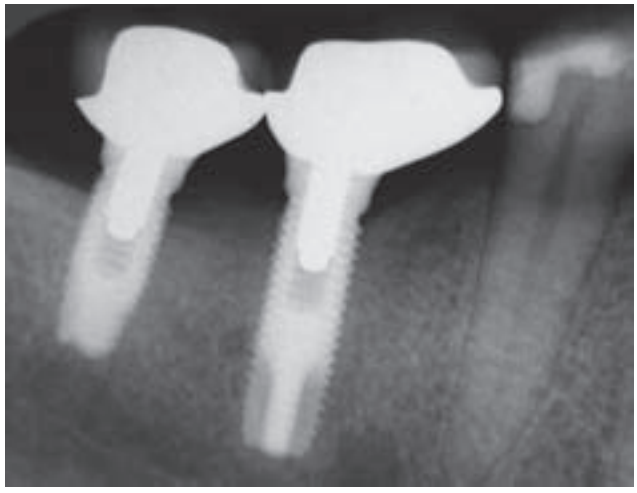


Fig. 9.7 Distally positioned implant (mandibular first molar) necessitating mesial projection of the restoration to compensate.

the facial aspect of the provisional prosthesis and allowed to overlap onto the borders of the master cast. Since three grooves had been cut into the borders of the cast, and the matrix has been adapted into these grooves, upon removal of the provisional prosthesis, the matrix remains attached to the cast, and displays the imprint of the facial aspect of the teeth. In addition, the indexed matrix can be removed and reproducibly reseated onto the cast, as needed. By placing guide pins into the implant analogs and relating them to the matrix as well as the opposing cast, a clear visualization of mesiodistal implant relationships can be observed (Fig. 9.8). Based on this information, decisions can be made with respect to the final prosthesis design. For the scenario depicted in Fig. 9.8, a screw-on porcelain fused to metal prosthesis was fabricated. This matrix evaluation technique can be used for the full arch, partial arch, or single-tooth cases.

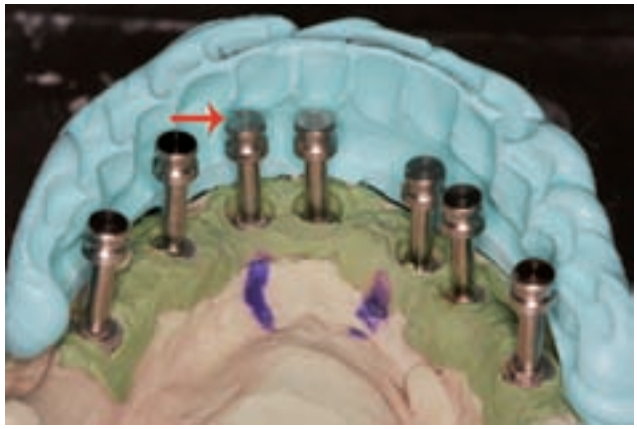
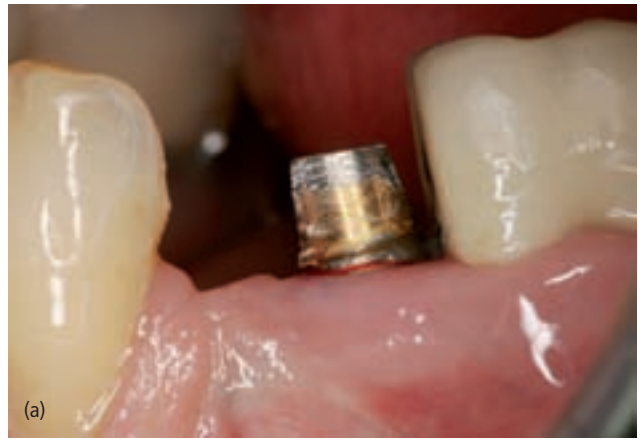


Fig. 9.8 Master cast with indexed elastomeric matrix demonstrating embrasure implant, i.e. implant positioned in the interproximal space in the canine–lateral incisor area (red arrow).

When a single implant is not in the mesiodistal center between adjacent teeth, a custom-made abutment can be fabricated to compensate for this issue. For example, in Fig. 9.9(a), the implant replacing the lower first premolar is distally positioned. An abutment that is flared to the mesial can be fabricated to compensate for this discrepancy. Alternately, the restoration can be fabricated to fill the excess space (Fig. 9.9b). Extending the mesial dimensions of the abutment allows the restoration to be "centered" within the edentate space. The corrected position of the restoration will help sculpt the soft tissue, or at least close the space to prevent food impaction. However, if the implant was not placed apically enough, there will be no running room, and the abutment or restoration will then have to transition in an abrupt manner from the cross-sectional diameter of the implant to the diameter of the tooth being replaced. This will create a mesial or distal partial-pontic (ridge lap-cantilever) effect. In addition, if the implant collar was placed above the gingival margin, it will result in an unsightly metal display.

When there are multiple implants with mesiodistal malposition, additional steps may be required to manage the problem and it may be necessary to alter the width of



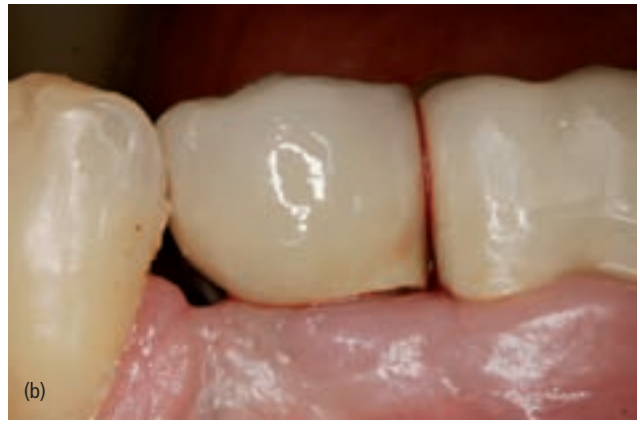
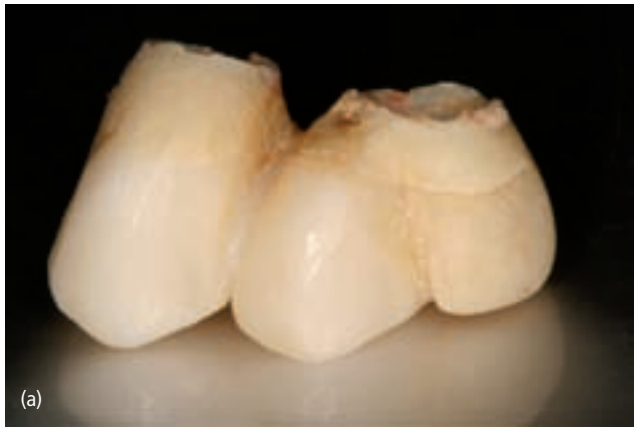


Fig. 9.9 (a) Distally positioned implant replacing the mandibular left second premolar. (b) Porcelain fused to metal cement-retained restoration fabricated to fill the excess space.

implant restorations and adjacent natural teeth to redistribute space (Fig. 9.10a, b). Two different scenarios may occur: too much space or too little space between adjacent teeth or implants. Too little space may cause injury to the interproximal bone (29) and soft tissue, and will necessitate restorations which are narrower than desired. If there is too much space between implants, an additional pontic can be cantilevered from the implants. However, the mesiodistal dimensions of the teeth may not approximate the contralateral teeth from an esthetic perspective. Furthermore, cantilevers will increase stress on supporting implants.

Implants in close proximity to each other need to be managed differently. For example, transfer copings on these implants may contact each other or adjacent teeth during impressioning. Solutions for this dilemma include selective grinding of adjacent natural teeth or reshaping of the transfer copings. If the problem is severe, impressions can be made with one transfer coping at a time. However, in this situation, creating adequate embrasures may be difficult and consideration must be given to developing adequate access for hygiene (Fig. 9.11). To compensate for this problem, abutments without a flare (straight abutments) should be used. This will use less space and afford the opportunity to create an adequate embrasure. In addition, at the time of prosthesis insertion, extra effort will be required to remove cement within the constricted embrasure (Fig. 9.12a, b). There may also be inadequate space to accommodate the horizontal biologic width of an implant (30), which can result in interimplant bone resorption and an unesthetic soft-tissue deficiency between adjacent prosthetic teeth (Fig. 9.13) (31, 32).

Fig. 9.11 Lingual view of a prosthesis fabricated on implants in close proximity. A floss threader passes through this embrasure with difficulty.



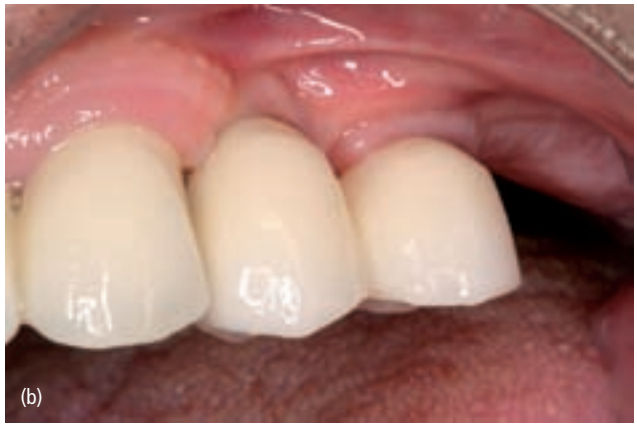
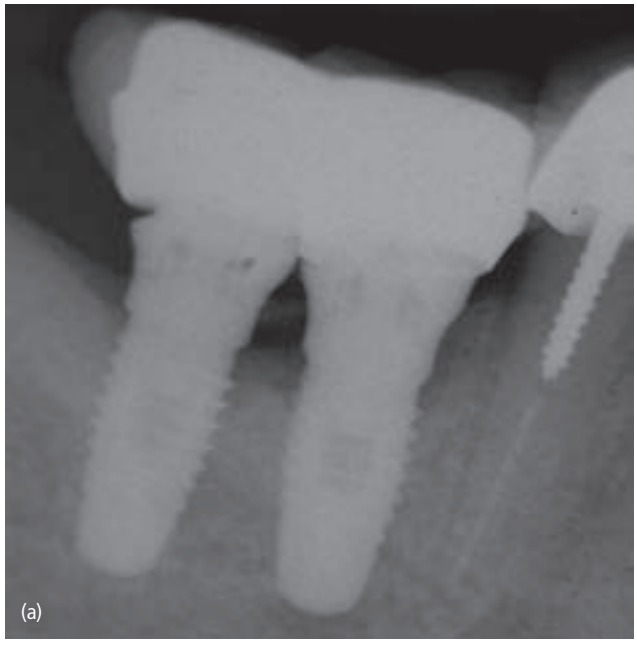


Fig. 9.10 (a) Facial view of provisional splint demonstrating insufficient room to fabricate three teeth. (b) Mesiodistal implant positioning allows for the fabrication of two premolars of slightly wider dimension (with patient approval).

Implants incorrectly positioned within the interproximal space fall within the category of mesiodistal malposition (Fig. 9.14). The matrix evaluation technique previously described can be used to identify these issues and plan the definitive prosthesis (Fig. 9.15). When an implant is positioned within the embrasure space, the facial dimension of the prosthesis will project labially from the malposed implant. The additional thickness that is necessary to compensate for this malposition must be accepted by the patient or else the implant cannot be used (Fig. 9.16).

Prevention of buccolingually or mesiodistally malposed implants is easy to conceptualize, but may be difficult to implement for a variety of reasons (e.g. anatomic limitations). The implant surgeon must clearly visualize the entry point of the osteotomy or must use information provided by the surgical guide. Malpositioned implants are less amenable to correction than other implant placement issues (e.g. angulation issues), even when angulated or custom abutments are used. In the esthetic zone, malposed implants can be problematic (see Chapter 8). They are more difficult to correct than misangulated implants, which will be addressed in the next section. Malposed implants in the esthetic zone may have to be removed and new implants placed (see Chapter 25). If it is determined at the time of surgical placement that an implant will be buccolingually or mesiodistally malpositioned, it is critical to add additional sink depth (apical positioning) of 1–2 mm. This maneuver will subsequently provide additional running room for the development of proper axial tooth contours.



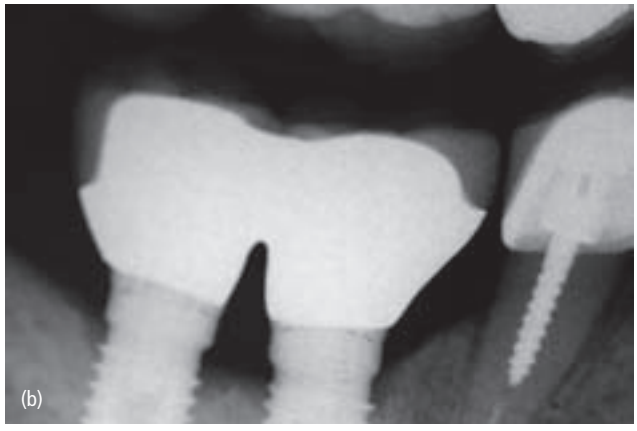


Fig. 9.12 (a) Radiograph of flared abutments which should not be used when implants are too close to each other. The embrasure is non-existent and cement remains subgingivally. (b) Radiograph demonstrating that the abutments have been reprepared or replaced and new restorations have been fabricated which demonstrate adequate marginal adaptation and a sufficient gingival embrasure.

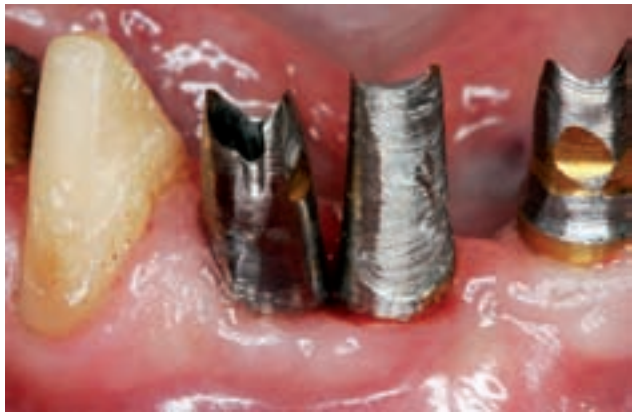


Fig. 9.13 Clinical view of two mandibular implants placed too close together.

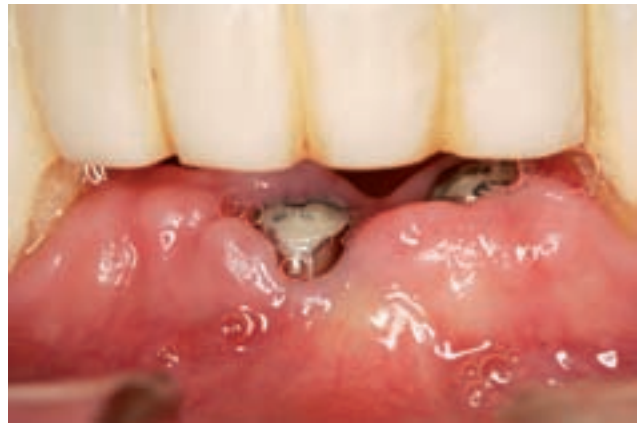


Fig. 9.14 Based on the contours of the provisional prosthesis, this implant is positioned in the interproximal embrasure.

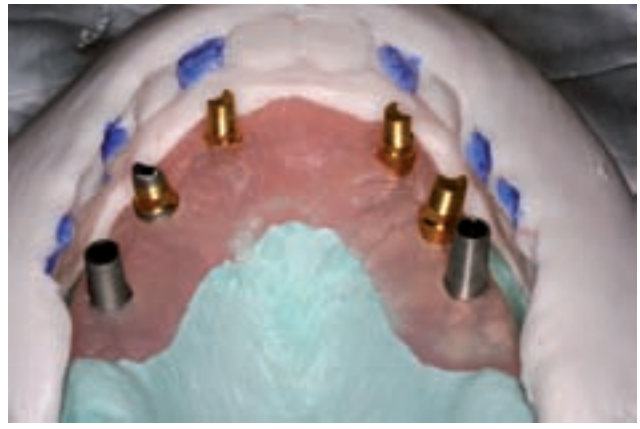


Fig. 9.15 Using matrix evaluation methodology, it becomes apparent that the patient's maxillary left lateral incisor abutment is positioned in the interproximal embrasure. This impacts the design of the definitive restoration.

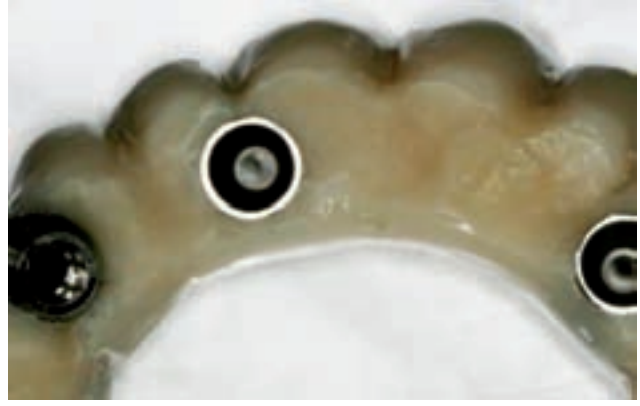


Fig. 9.16 Prosthesis accommodating embrasure implant. Note that the prosthesis must project labially from the implant by the thickness of the abutment plus the restorative materials.

Angulation issues

An implant's angulation is determined by the drill's trajectory as it proceeds into the bone. With respect to implant angulation, it is appropriate to establish a balance between prosthetic and anatomic concerns. For example, an implant's prosthetic platform may be in the correct position, but the implant may have to be angled to avoid surgical fenestration of the labial bone when there is a concavity in the anterior maxilla or the lingual cortical plate in the mandible (33–35).

Buccolingual angulation issues

An implant may be placed in the correct position, but its trajectory may be misaligned. This may result in a minor misangulation (0–15 degrees) or a severe misangulation (> 25 degrees). Misangulations up to 15 degrees are easy to manage. Most prefabricated abutments are available in 0–15 degree configurations. Components can be custom cast to correct more extreme implant angulation issues (e.g. 25°, 35°) (Fig. 9.17a, b). Correcting angulation issues becomes more difficult when parallelism between multiple abutments must be achieved. When multiple abutments need to be aligned, consideration should be given to inserting additional implant(s) and segmenting the prosthesis to facilitate attaining parallelism.

A major concern pertaining to correction of buccolingual angulation issues is the amount of available running room. Angulated components require additional crevicular space (running room) to allow them to correct the angulation issue before the abutment continues coronally to retain the prosthesis. If the implant is not placed apically enough (not enough running room), the metal is likely to be visible, creating an esthetic problem (Fig. 9.18). In addition, high stresses placed on the implant–abutment interface of angled implants can lead to abutment screw loosening, screw fracture, or fracture of the coronal aspect of an implant (Fig. 9.19) (36, 37). The greater masticatory forces that exist in the posterior areas compared to the anterior segments of the mouth can exacerbate these complications (38, 39). From a functional perspective, additional implants can be placed to provide additional support if severe implant angulation cannot be avoided.

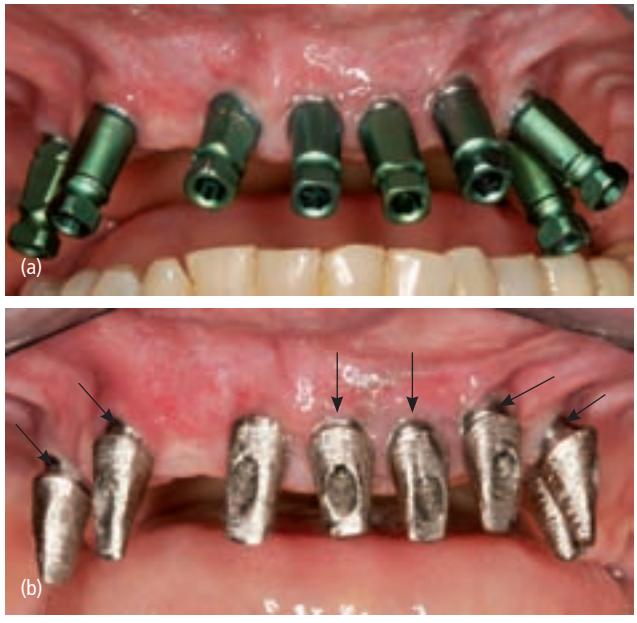


Fig. 9.17 (a) Intraoral view of minor and severe labial angulation of multiple implants. (b) Severely (malpositioned and) misangulated implants with base of abutments and coronal aspect of implants visible (black arrows).

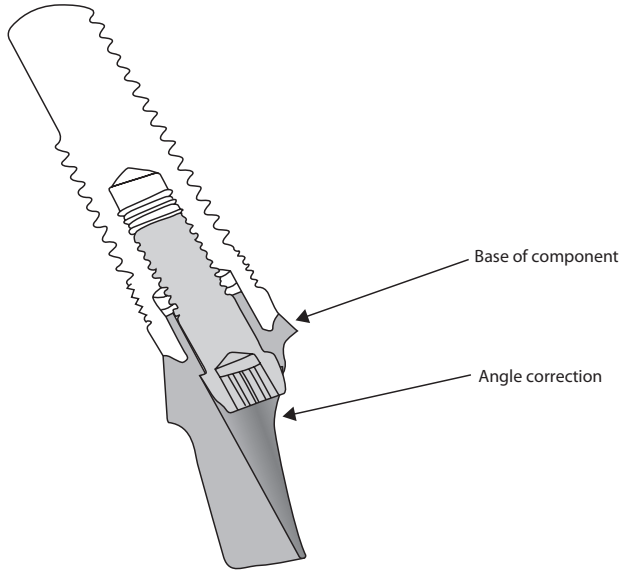


Fig. 9.18 Diagram of the labial base of the abutment, which must remain subgingival for optimal esthetics. Running room is required to accomplish this.

Mesiodistal angulation issues

Minor mesiodistal angulation issues are sometimes precipitated by the anatomy at the intended implantation site. For example, the need to avoid the root of an adjacent tooth or a vital structure (such as the mental foramen), or the desire to avoid penetration of the maxillary sinus may dictate angulating the implant. This problem becomes evident upon visual inspection or when the coronal aspect of a transfer coping makes contact with an adjacent tooth or transfer coping. To correct this problem, the side of the transfer coping can be reduced. However, if the trajectory is severe, an implant-level transfer impression may not be possible. When this occurs, an angulated abutment can be selected based on visual inspection of the implant's trajectory and assessment of the crevicular depth. If multiple implants are

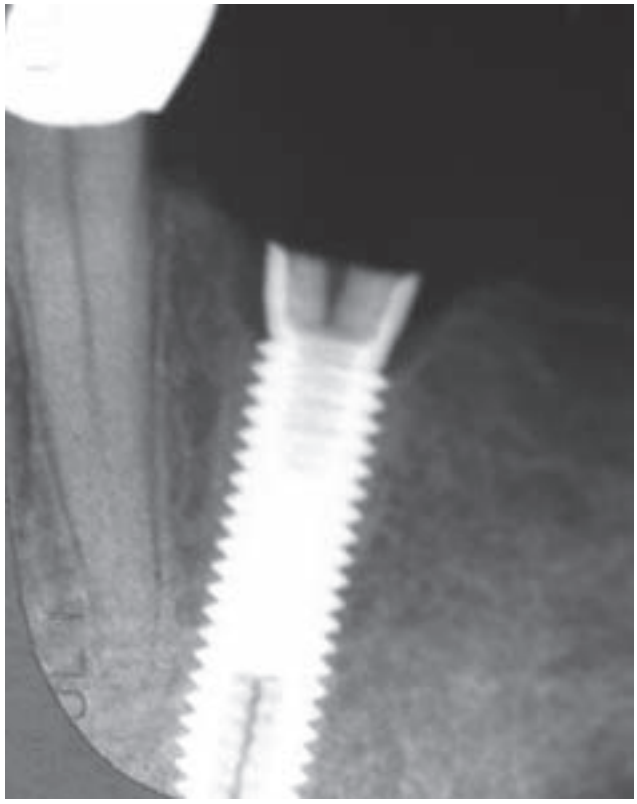


Fig. 9.19 Radiographic view of fracture (flowering) of the coronal aspect of an implant.

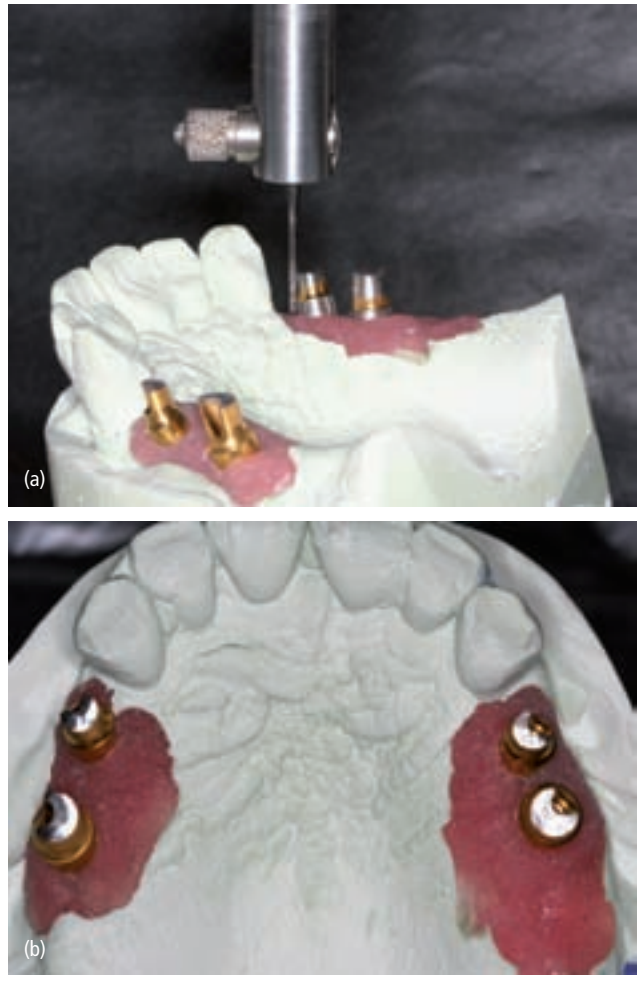


Fig. 9.20 (a) Maxillary master cast demonstrating abutments on implants with mesiodistal angulations being surveyed for a line of draw and parallelism. Implants were placed in this manner to avoid contact with canine roots. (b) Prepared 15 degree prefabricated angulated abutments correcting implant angulations.

involved, making implant-level impressions with one transfer coping at a time is an option. In this situation, additional running room is beneficial, because it avoids abrupt contours and unsightly display of the transgingival portions of the metal abutments. Occasionally, if the problem is severe, it may be necessary to submerge or remove an implant.

In general, aberrant trajectories caused by misangulated implants are corrected by using angulated components to provide parallelism between abutments. Pertinently, the 15 degree angulation of a prefabricated abutment can correct a mesially or distally angled implant, similar in dimension to the correction of a buccolingual angulation issue (Fig. 9.20a, b). Correcting an angulation issue with a 15 degree angled abutment can shift a restoration approximately 1–1.5 mm at the occlusal aspect, and a 25 degree abutment can shift a prosthesis 2–2.5 mm. This can be conceptualized as an angulation correction and a coronal positional shift as well.

To provide a satisfactory prosthetic result, when correcting angulation errors, adequate running room is needed to ensure a gradual emergence profile (Fig. 9.21a, b). Failure to develop a gradual emergence profile results in a restoration surrounded by a large gingival embrasure, or requires a circumferential ridge lap, which may be predisposed to food impaction and hygiene difficulties. In addition, mesiodistal angulation issues combined with inadequate running room in the esthetic zone can result in a metal abutment being exposed, which may be unesthetic (Fig. 9.22). Patients with low smile lines may accept this prosthetic solution. However, prostheses fabricated on misangulated implants are subject to additional forces, which may contribute to premature mechanical failures.

Apico-occlusal issues (sink depth)

Sink depth is the apico-occlusal position of an implant; it is a powerful compensatory mechanism for positional and angulation issues. Increasing the sink depth, which adds to the available running room, facilitates providing a restoration with gradual axial contours. There are several factors that must be considered when planning the apicocoronal location of an implant. These include interocclusal clearance, bone level, tissue thickness, implant

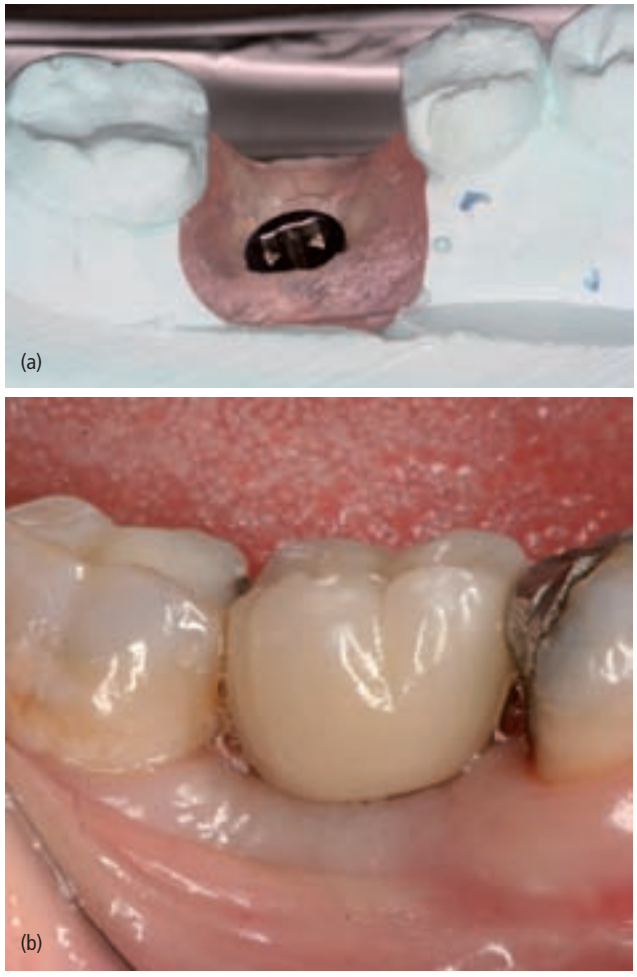


Fig. 9.21 (a) Lingual view of implant manifesting distal angulation on a master cast. The angulated abutment will use running room to correct angulation while still within the soft-tissue crevice. (b) Facial clinical view of restoration on distally angulated implant. By using available running room, there is no unsightly display of the metal abutment.

malposition or misangulation, and the impact of adjacent sequential extractions.

Interocclusal clearance

Space considerations related to the opposing arch are important to ensure a successful prosthetic result. This factor can be assessed by visual inspection of study casts before implant surgery. During implant placement, failure to have the patient close into intercuspal tooth position may result in a miscalculation of the amount of space available for a restoration. At the time of surgery, adjustments in sink depth can easily be made. For instance, a shorter implant can be selected and placed more apically. However, once implant integration has occurred, prosthetic management is the only available solution if the implant is to be placed in function.

Before implant placement, it is necessary to calculate the space needed to accommodate implant components

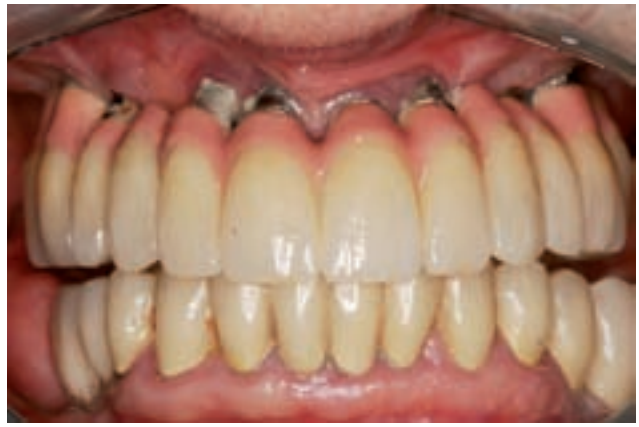


Fig. 9.22 Mesiodistal (and buccal) angulation issue combined with inadequate running room (minimal sink depth). Note plaque accumulation in gingival areas.

and the final restoration. For example, a cementable single restoration would minimally require 7 mm of clearance from the implant platform to the opposing dentition. The dimensions of components comprising the interocclusal space are as follows: 2 mm for occlusal clearance between the abutment and the opposing tooth, a minimum of 4.5 mm "prep" length, which assumes excellent parallelism, and 0.5 mm for the abutment's polished collar to interface with the implant (40–42). If there is reduced interocclusal space (e.g. 4.5–5 mm), a screw-on restoration can be fabricated (also referred to as a UCLA-type crown) (Fig. 9.23a, b) (43). At the time of surgery, measurements should be taken that account for gingival thickness and the level of the osseous crest. If necessary, ridge ostectomy can be performed to create additional interocclusal clearance. In addition, an implant can be placed coronal, apical, or level with the osseous crest to accommodate the size of the future restoration. When these measurements are made during the restorative phase, options are limited to a decision to fabricate a cement versus a screw-retained restoration. Occasionally, a small amount of prosthetic space can be gained by selective equilibration of the opposing dentition. From a different perspective, if the vertical dimension is to be restored, interocclusal space will become available by opening the bite.

Bone level

An implant may have a shallow tissue crevice, but still be in an apical position relative to an adjacent tooth or implant. This can occur when implants are placed into ridges that underwent vertical osseous resorption before implant placement (44–46). If implants are placed into these areas without site development, excessive discrepancy in levels of the gingiva may exist between the implant and the adjacent tooth. This results in an uneven gingival topography. If the restoration is within the

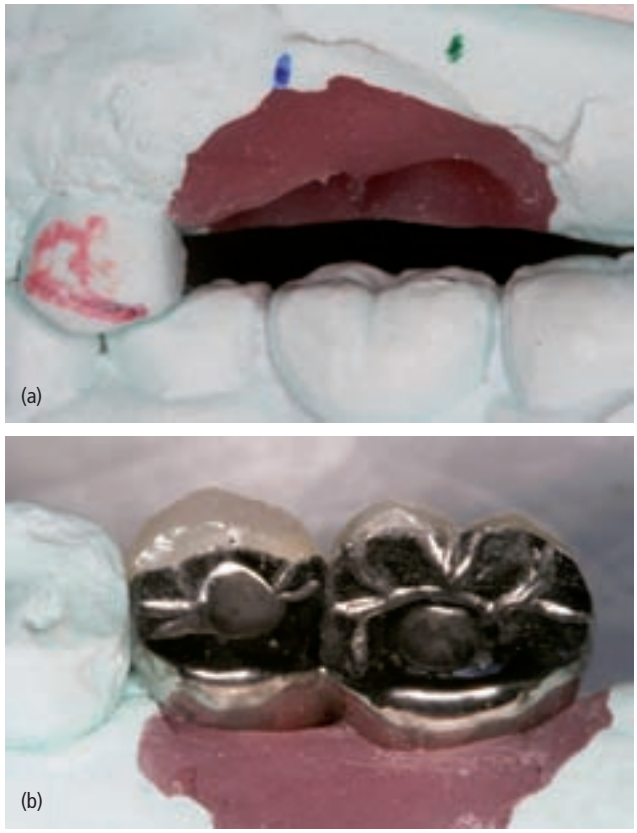


Fig. 9.23 (a) Facial view of limited interocclusal space (5 mm) necessitates fabrication of a screw-on prosthesis (as opposed to a cement-on restoration). (b) Occlusal–lingual view of completed screw-on prosthesis.

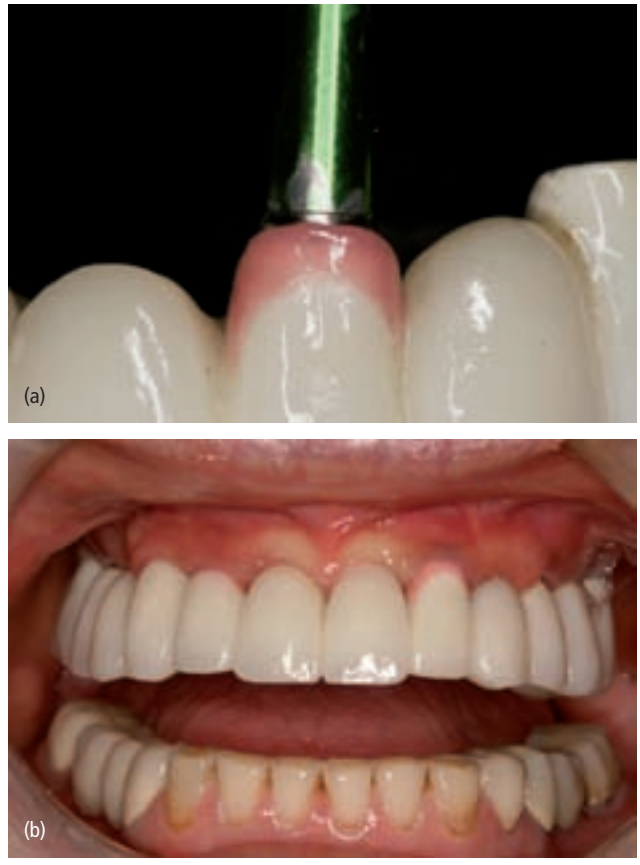


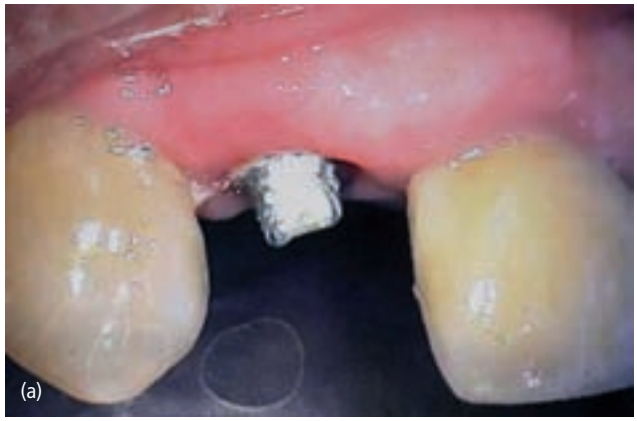
Fig. 9.24 (a) Final restoration with pink ceramic labial "soft tissue" necessitated by insufficient site development prior to implant placement. (b) Intraoral retracted view of completed porcelain fused to metal cement-retained prosthesis. Note pink ceramics at the gingival area of the left lateral incisor.

esthetic zone, the use of pink ceramics (or composite) may partially conceal the disharmony in the gingival heights (Fig. 9.24a, b) (47). Otherwise, a long clinical crown can be fabricated and considered acceptable when it is concealed by the patient's lip. Therefore, existing discrepancies in bone levels must be considered during the planning phase of therapy. To accommodate these incongruities and to achieve a satisfactory prosthetic result, it may be beneficial to use a computed tomographic (CT) scan and a surgical template to delineate between the tooth portion of the future restoration and the missing soft and hard tissues. If these irregularities pose a problem in attaining patient satisfaction with respect to esthetics, the potential for regeneration of tissue deficiencies must be evaluated and discussed during the diagnostic and presurgical phases of treatment.

Gingival tissue thickness

Periodontal probing is the best way to measure the depth of an implant in relation to the gingival margin. Deep probing depths around an implant may be due to soft-tissue thickness. If deep probing depths occur as the result of thick tissue and the implant is not within the patient's esthetic zone, the tissues may be surgically thinned to create a shallow crevice. However, if this would result in a visible soft-tissue deformity, the deeper crevice should be retained. Accordingly, an abutment with a longer transgingival section can be used to compensate for the gingival thickness (Fig. 9.25a, b). However, implant crevices with deep probing depths may be associated with increased inflammation (mucositis), since they are more difficult for personal and professional maintenance. Therefore, patients must be informed of their responsibilities to care for these areas and maintenance regimens should be monitored.

From another perspective, deep crevices can impede the complete seating of prosthetic components (Fig. 9.26). This is often recognized on radiographs that include the implant–abutment junction. Even with internal connections, transfer copings or other prosthetic components may not seat if obstructed by unyielding tissue lining a deep crevice. The following techniques can be used to correct this problem. Local anesthesia is administered and flared or contoured abutments are inserted to nonsurgically distend the crevice (Fig. 9.27a, b). A radiograph should then be taken to confirm complete seating of the component. The tissues will blanch and after approxi-



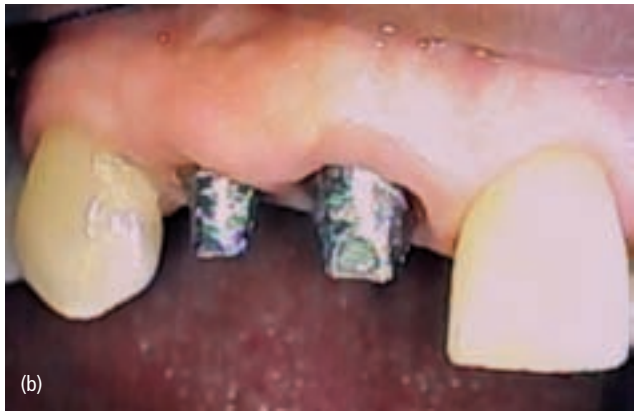


Fig. 9.25 (a) Clinical view of thick soft tissue and an abutment that was too short to traverse the tissue and provide retention for the restoration. As a result, the crown was repeatedly being dislodged. (b) Clinical view of abutments with adequate length for retention of the cement-on restoration and which traversed the soft-tissue thickness.

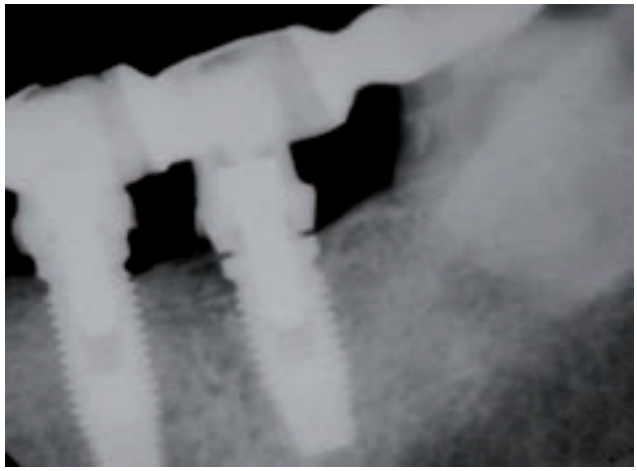
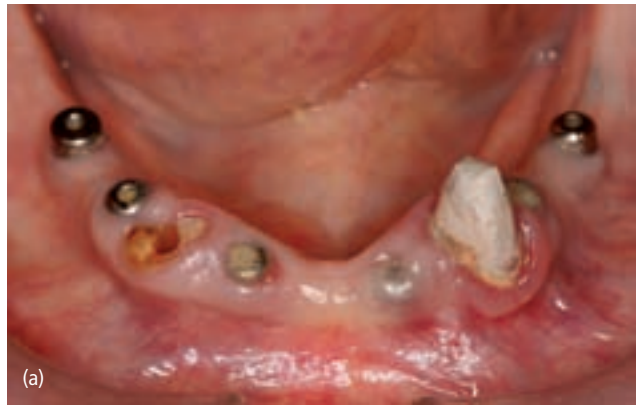


Fig. 9.26 Radiograph of an abutment on an externally hexed implant that is not completely seated.

mately 15 minutes, the soft tissue will expand to allow seating of the desired restorative component, and treatment can proceed. Occasionally, two small incisions need to be made interproximally to release the tension on the crevicular tissue. Sutures are rarely needed



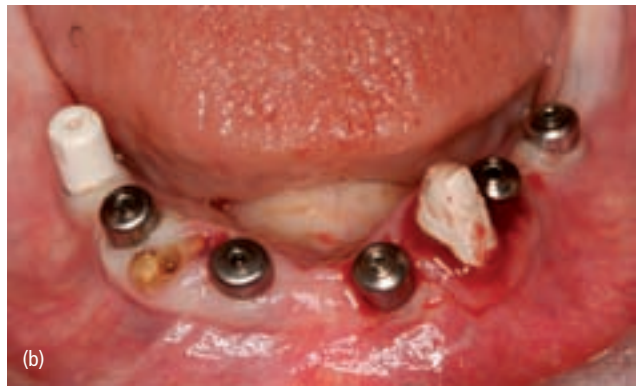
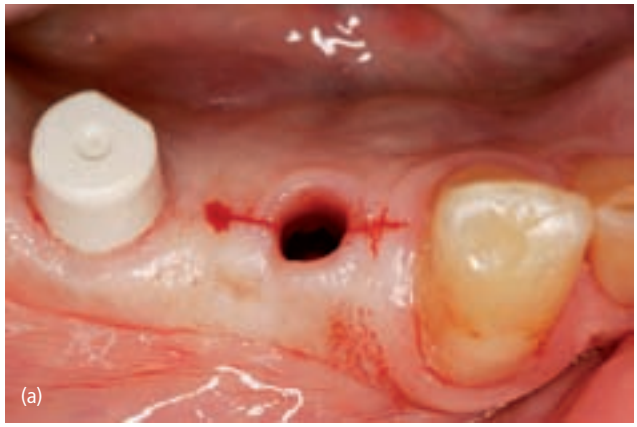


Fig. 9.27 (a) Intraoral view of narrow healing abutments placed at implant insertion. (b) At uncovering, wider healing abutments can be used to distend the crevice to a more prosthetically useful size.

(Fig. 9.28a, b). Once the crevicular tissue has been reshaped, optimally shaped interim (Fig. 9.29) or definitive components (Fig. 9.30a, b) can preserve the desired soft-tissue contour (48, 49).

Depth as a compensatory measure for malpositioned or misangulated implants

As previously mentioned, there are situations when implant malposition or misangulation is necessary. In this regard, if an implant is placed off angle, additional apical positioning will provide supplementary running room to allow for a gradual emergence of the prosthesis. For example, a maxillary anterior ridge may have sufficient bone to accommodate an implant; however, to avoid perforation of the labial plate of bone into a concavity, the implant may have to be inserted at an angle greater than desired. This increased implant angulation may be corrected with an angled abutment. An additional millimeter of sink depth will provide a more gradual correction of the angulation and establish proper tooth form (Fig. 9.31a–c). This technique is not a panacea. There are limits to compensating for misangled implants, and it is especially difficult to correct for malpositioned implants.



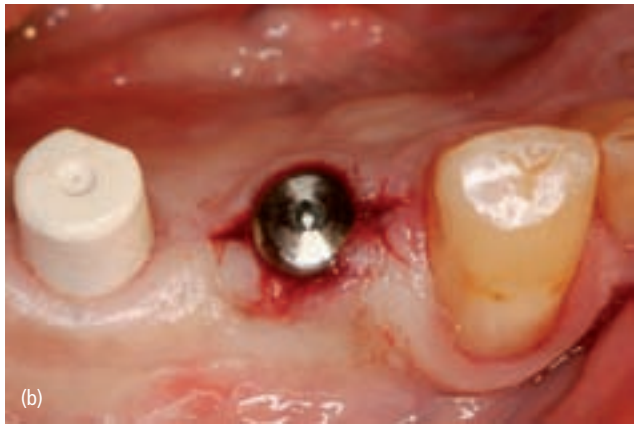


Fig. 9.28 (a) Interproximal incisions placed to allow for additional tissue expansion to accommodate flared healing collar. (b) Wider healing collar seated without difficulty.

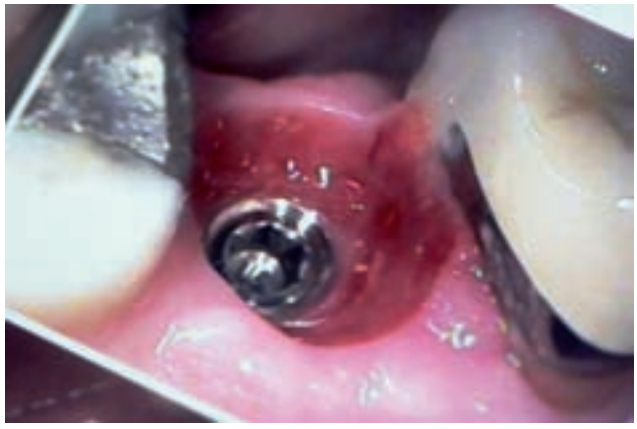
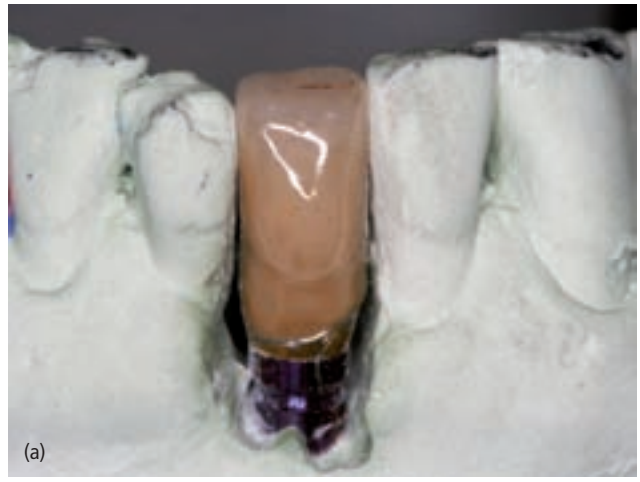


Fig. 9.29 Optimally shaped (ovoid) crevicular tissue for a maxillary second premolar. This was accomplished using an anatomically correct provisional crown.

Sink depth as compensation for planned extractions

Tooth removal results in both horizontal and vertical resorption of surrounding bone (50–52). When extractions are performed adjacent to implants, bone healing may result in gingival recession and exposure of implant components. Pertinently, when an implant is placed between teeth that are to be extracted, it should be placed more apically than usual in anticipation of ridge resorption that will occur as the socket heals. Furthermore, clinicians should be aware that multiple extractions adjacent to each other often result in more vertical bone loss than usually observed after one extraction. The amount of resorption that will occur is not predictable; however, it is prudent to provide additional running room in these situations (e.g. 1–2mm).



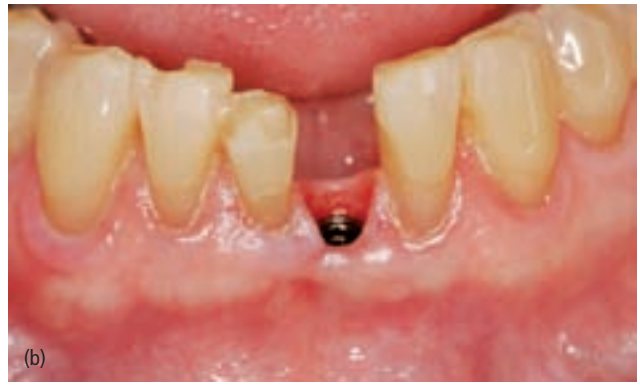
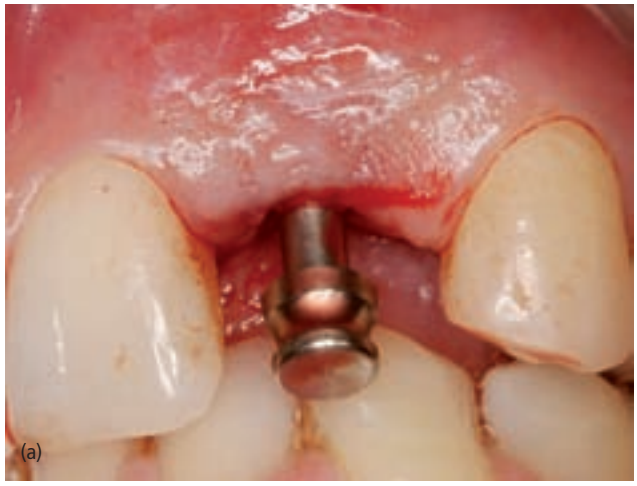


Fig. 9.30 (a) Definitive abutment and restoration used to shape or to preserve the already shaped crevicular tissue. (b) Intraoral view of optimal triangular shape of peri-implant crevice of a mandibular incisor.

Implants with insufficient apical positioning

Implants inserted without providing sufficient crevicular depth result in metal display that detracts from an esthetic result (Fig. 9.32). In addition, without running room, an abrupt change in diameter from the implant's prosthetic platform to the diameter of the restoration may be required. This may necessitate a ridge lap or a restoration that looks like a mushroom. It will trap food cervically and is difficult for the patient to maintain hygienically (Fig. 9.33a, b).



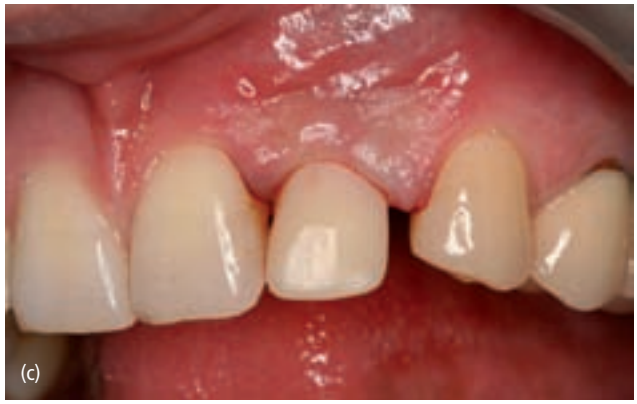


Fig. 9.31 (a) Implant placed more apically while angled to the labial to avoid incisal edges of the lower teeth in a patient with a deep bite; additional running room permits gradual emergence profile of restoration. (b) Provisional crown with gradual axial contours from the platform of the implant to the cervical area of the restoration. (c) Clinical view of the provisional crown at insertion. In the esthetic zone, allowing this tissue to respond to non-surgical sculpting for 2–3 months is recommended.

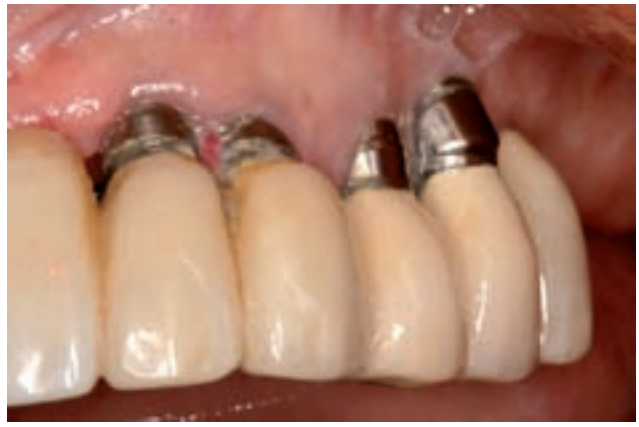
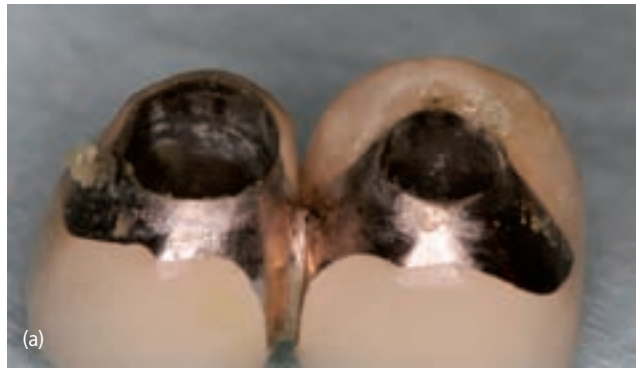


Fig. 9.32 Clinical view of implant platforms coronal to the free gingival margin resulting in an objectionable metal display.



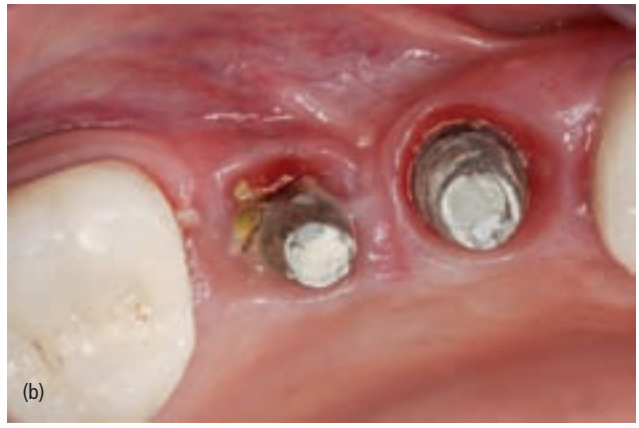


Fig. 9.33 (a) Restoration with facial ridge lap that could not be adequately cleaned by the patient. (b) Peri-implant disease which caused failure and resulted in implant removal.

Several techniques can be employed if an implant is not placed apically enough. An abutment with a short transgingival section can be used. Otherwise, the abutment and the coronal portion of the implant can be prepared subgingivally. This will hide the metal collar and increase abutment retention form to retain the restoration. However, the implant should not be overprepared, because it will weaken the metal. Alternately, a screw-on restoration can be fabricated. If the implant is already

supragingival, a screw-on restoration with a ridge lap can be fabricated, but this may create hygienic problems.

Take-home hints

- Problems relating to implant malposition can be avoided by evaluating study casts or wax-ups for proper form before fabricating a radiographic template.
- Problems relating to implant malposition can be avoided by converting radiographic guides into surgical templates to ensure proper implant insertions.
- Major implant placement issues can be avoided by using diagnostic information offered by CT technology, which provides 3D assessments of alveolar ridges before a surgical intervention.
- It is possible to avoid major implant placement difficulties by using ridge augmentation techniques before implant insertion.
- Difficulty in seating transfer copings into implants which are surrounded by narrow tissue crevices can be prevented or treated using flared healing abutments to distend the peri-implant crevice non-surgically before impression procedures.
- At the start of the prosthetic phase of treatment, evaluation of implant locations is facilitated using a facial elastomeric matrix of the provisional prosthesis superimposed on an implant-level master cast.
- During the surgical placement of an implant, if it is deemed necessary to accept an angulation that is 15–25 degrees (off vertical), then additional sink depth will provide more running room and permit fabrication of a restoration with proper tooth contours (no ridge laps).
- To facilitate optimal implant placement and restoration, it is essential that clinicians receive adequate formal training and experience before undertaking implant-related surgical and prosthetic procedures.

References

1. Adell R, Lekholm U, Rockler B, Brånemark P-I. A 15 year study of osseointegrated implants in the treatment of the edentulous jaw. *Int J Oral Surg* 1981; **10**: 387–16.
2. Cox JF, Zarb GA. The longitudinal clinical efficacy in osseointegrated dental implants: a 3-year report. *Int J Oral Maxillofac Implants* 1987; **2**: 91–100.
3. Van Steenberghe D, Quirynen M, Calberson L, Demanet M. A prospective evaluation of the fate of 697 consecutive intraoral fixtures and modem Brånemark in the rehabilitation of edentulism. *J Head Neck Pathol* 1987; **6**: 53–8.
4. Adell R, Eriksson B, Lekholm U, Brånemark P-I, Jemt T. A long-term follow up study of osseointegrated implants in the treatment of totally edentulous jaws. *Int J Oral Maxillofac Implants* 1990; **5**: 347–59.
5. Bengazi F, Wennstrom JL, Lekholm U. Recession of the soft tissue margin at oral implants. A 2-year longitudinal study prospective study. *Clin Oral Implants Res* 1996; **7**: 303–10.
6. Jemt T, Book K, Lindén B, Urde G. Failures and complications in 92 consecutively inserted overdentures supported by Brånemark implants in severely resorbed edentulous maxillae: a study from prosthetic treatment to first annual check-up. *Int J Oral Maxillofac Implants* 1992; **7**: 162–7.
7. Jemt T, Lindén B, Lekholm U. Failures and complications in 127 consecutively placed fixed partial prostheses supported by Brånemark implants: from prosthetic treatment to first annual checkup. *Int J Oral Maxillofac Implants* 1992; **7**: 40–4.
8. Ekfeldt A, Christiansson U, Eriksson T, Lindén U, Lundqvist S, Rundcrantz T, *et al*. A retrospective analysis of factors associated with multiple implant failures in maxillae. *Clin Oral Implants Res* 2001; **12**: 462–7.
9. Rothman S. Use of prosthesis-generated computerized tomographic information for diagnosis and surgical treatment planning. In: Rothman S, ed. *Dental applications of computerized tomography*. Berlin: Quintessence, 1998: 177– 239.
10. Garg AK. *Bone: biology, harvesting, grafting for dental implants – rationale and clinical applications.* Berlin: Quintessence, 2004: 21–56.
11. Simion M, Scarano A, Luca G, Piatelli A. Treatment of dehiscences and fenestrations around dental implants using resorbable and nonresorbable membranes associated with bone autografts: a comparative clinical study. *Int J Oral Maxollofac Implants* 1997; **12**: 159–67.
12. Raghoebar GM, Batenburg RH, Meijer HJ, Vissink A. Horizontal osteotomy for reconstruction of the narrow edentulous mandible. *Clin Oral Implants Res* 2000; **11**: 76–82.
13. Pikos, M. Block autografts for localized ridge augmentation: Part 1. The posterior maxilla. *Implant Dent* 1999; **8**: 279–85.
14. Tinti C, Parma-Benfanati S. Vertical ridge augmentation: surgical protocol and retrospective evaluation of 48 consecutively inserted implants. *Int J Periodont Restor Dent* 1998; **18**: 434–43.
15. Zitzman NU, Naef R, Scharer P. Resorbable vs. nonresorbable membranes in combination with Bio-Oss for guided bone regeneration. *Int J Oral Maxollofac Implants* 1997; **12**: 844–52.
16. Sadan A, Raigrodski AJ, Salinas TJ. Prosthetic considerations in the fabrication of surgical stents for implant placement. *Pract Periodont Aesthet Dent* 1997; **9**: 1003– 11.
17. Sclar A. *Soft tissue and esthetic considerations in implant dentistry*. Berlin: Quintessence, 2004: 1–5.
18. Zamzok J. Nonsurgical soft tissue sculpting. *Alpha Omegan* 1997; **90**: 65–9.
19. Kraus BS, Jordan RE Abrams A. *Dental anatomy and occlusion: a study of the masticatory system*. Baltimore, MD: Williams and Wilkins, 1969: 5–32.

20. Greenstein G, Cavallaro J. The relationship between biologic concepts and fabrication of surgical guides for dental implant placement. *Compend Contin Educ Dent* 2007; **28**: 196–203.
21. Froum SJ, Coran M, Thaller B, Kushner L, Scopp IW, Stahl SS. Periodontal healing following open débridement flap procedures. I. Clinical assessment of soft tissue and osseous repair. *J Periodontol* 1982; **53**: 8–14.
22. Stahl SS, Froum SJ, Kushner L. Periodontal healing following open débridement flap procedures. II. Histologic observations. *J Periodontol* 1982; **53**: 15–21.
23. Araújo MG, Sukekava F, Wennström JL, Lindhe J. Ridge alterations following implant placement in fresh extraction sockets: an experimental study in the dog. *J Clin Periodontol* 2005; **32**: 645–52.
24. Moghaddas H, Stahl SS. Alveolar bone remodeling following osseous surgery. A clinical study. *J Periodontol* 1980; **51**: 376–81.
25. Pennel BM, King KO, Wilderman MN, Barron JM. Repair of the alveolar process following osseous surgery. *J Periodontol* 1967; **38**: 426–31.
26. Wilderman MN, Pennel BM, King K, Barron JM. Histogenesis of repair following osseous surgery. *J Periodontol* 1970; **41**: 551–65.
27. Grunder U, Gracis S, Capelli M. Influence of the 3-D bone-to-implant relationship on esthetics. *Int J Periodont Restor Dent* 2005; **25**: 113–19.
28. Kuwata M. *Theory and practice for ceramo-metal restorations.* Berlin: Quintessence, 1980: 13–34.
29. Esposito M, Ekestubbe A, Gröndahl K. Radiological evaluation of marginal bone loss at tooth surfaces facing single Brånemark implants. *Clin Oral Implants Res* 1993; **4**: 151–7.
30. Tarnow DP, Cho SC, Wallace SS. The effect of inter-implant distance on the height of inter-implant bone crest. *J Periodontol* 2000; **71**: 546–9.
31. Tarnow D, Elian N, Fletcher P, Froum S, Magner A, Cho SC, *et al*. Vertical distance from the crest of bone to the height of the interproximal papilla between adjacent implants. *J Periodontol* 2003; **74**: 1785– 8.
32. Elian N, Jalbout ZN, Cho SC, Froum S, Tarnow DP. Realities and limitations in the management of the interdental papilla between implants: three case reports. *Pract Proced Aesthet Dent* 2003; **15**: 737–44.
33. Greenstein G, Cavallaro J, Romanos G, Tarnow D. Clinical recommendations for avoiding and managing surgical complications associated with implant dentistry: a review. *J Periodontol* 2008; **79**: 1317–29.
34. Greenstein G, Cavallaro J, Tarnow D. Practical application of anatomy for the dental implant surgeon. *J Periodontol* 2008; **79**: 1833–46.
35. ten Bruggenkate CM, Krekeler G, Kraaijenhagen HA, Foitzik C, Oosterbeek HS. Hemorrhage of the floor of the mouth resulting from lingual perforation during implant placement: a clinical report. *Int J Oral Maxillofac Implants* 1993; **8**: 329–34.
36. Zarb GA, Schmitt A. The longitudinal clinical effectiveness of osseointegrated dental implants: The Toronto study. Part III: Problems and complications encountered. *J Prosthet Dent* 1990; **64**: 185–94.
37. Brosh T, Pilo R, Sudai D. The influence of abutment angulation on strains and stresses along the implant/bone interface: comparison between two experimental techniques. *J Prosthet Dent* 1998; **79**: 328–34.
38. Lundgren D, Laurell L. Occlusal forces in prosthetically restored dentitions: a methodological study. *J Oral Rehabil* 1984; **11**: 29–37.
39. Pjetursson BE, Tan K, Lang NP, Brägger U, Egger M, Zwahlen M. A systematic review of the survival and complication rates of fixed partial dentures (FPDs) after an observation period of at least 5 years. I. Implant-supported FPDs. *Clin Oral Implants Res* 2004; **15**: 667–76.
40. Potts RG, Shillingburg HT Jr, Duncanson MG Jr. Retention and resistance of preparations for cast restorations. *J Prosthet Dent* 2004; **92**: 207–12.
41. Kent WA, Shillingburg HT Jr, Duncanson MG Jr. Taper of clinical preparations for cast restorations. *Quintessence Int* 1988; **19**: 339–45.
42. Potts RG, Shillingburg HT Jr, Duncanson MG Jr. Retention and resistance of preparations for cast restorations. *J Prosthet Dent* 1980; **43**: 303–8.
43. Binon PP. Implants and components: entering the new millennium. *Int J Oral Maxillofac Implants* 2000; **15**: 76–94.
44. Tallgren A. The continuing reduction of the residual alveolar ridges in complete denture wearers: a mixed-longitudinal study covering 25 years. 1972. *J Prosthet Dent* 2003; **89**: 427–35.
45. Tallgren A, Lang BR, Walker GF, Ash MM Jr. Roentgen cephalometric analysis of ridge resorption and changes in jaw and occlusal relationships in immediate complete denture wearers. *J Oral Rehabil* 1980; **7**: 77–94.
46. Chan MF, Howell RA, Cawood JI. Prosthetic rehabilitation of the atrophic maxilla using pre-implant surgery and endosseous implants. *Br Dent J* 1996; **181**: 51–8.
47. Garcia LT, Verrett RG. Metal-ceramic restorations – custom characterization with pink porcelain. *Compend Contin Educ Dent* 2004; **25**: 242–6.
48. Macintosh D. Method for developing an optimal emergence profile using heat-polymerized provisional restorations for single-tooth implant-supported restorations. *J Prosthet Dent* 2004; **91**: 289–92.
49. Elian N, Tabourian G, Jalbout Z, Classi A, Cho SC, Froum S, Tarnow D. Accurate transfer of peri-implant soft tissue emergence profile from the provisional crown to the final prosthesis using an emergence profile cast. *J Esthet Restor Dent* 2007; **19**: 306–14.
50. Botticelli D, Berglundh T, Lindhe J. Hard-tissue alterations following immediate implant placement in extraction sites. *J Clin Periodontol* 2004; **31**: 820–8.
51. Araújo MG, Lindhe J. Dimensional ridge alterations following tooth extraction. An experimental study in the dog. *J Clin Periodontol* 2005; **32**: 212–18.
52. Araújo MG, Sukekava F, Wennström JL, Lindhe J. Ridge alterations following implant placement in fresh extraction sockets: an experimental study in the dog. *J Clin Periodontol* 2005; **32**: 645–52.

Chapter 10

Prosthetic-related dental implant complications: etiology, prevention, and treatment

Charles J. Goodacre DDS, MSD *and Mathew T. Kattadiyil* BDS, MDS, MS

Introduction

The high success rate of osseointegrated dental implants has been well documented; however, complications and failures do occur (1). Complications have been defined as secondary conditions that develop during or after implant surgery or prosthesis placement. While the occurrence of a complication may indicate that inadequate care was provided, in most situations this is not the case. In addition, complications are not always associated with failure; in fact, most complications do not produce failure. However, they are frequently bothersome because of our inability to predict their occurrence and the need to provide additional care on an unexpected and sometimes emergency basis.

Implant success has been defined as immobility of the implants; absence of peri-implant radiolucency; annual vertical bone loss of less than 0.2 mm after the first year following implant placement; the absence of pain, infections, paresthesia, neuropathies, or violation of the mandibular canal; and a success rate of 85% after 5 years and 80% at the end of a 10-year period (2).

Etiology and timing of complications and failure

The reasons for complications and failure of dental implants and associated crowns and prostheses are multifactorial. They may be caused by inadequate treatment planning, host systemic factors, the surgical procedure itself, or by early- and late-occurring factors.

Early failures may be due to undiagnosed systemic diseases, inadequate bone at the implant site, systemic factors such as smoking, recent radiation therapy, overly traumatic surgical technique, bacterial contamination or infection, premature loading, or inadequate homecare.

Late failures occur during the prosthodontic treatment and maintenance phases after initial successful osseointegration and might be due to a lack of equilibrium between biomechanical factors and host factors.

Preventing implant complications is enhanced by sound diagnosis and treatment planning, good surgical technique (3), appropriate spacing and alignment of implants (4), use of surgical guides or templates, proper postoperative management, fabrication and placement of a passively seated stress-distributing prosthesis (5), meticulous oral hygiene, and effective and periodic long-term maintenance. In the initial publication regarding the clinical use of osseointegrated implants in the treatment of edentulous patients (6), the authors made the following profound statement: "Atraumatic surgery must be followed by atraumatic prosthodontics, i.e. a prosthodontic treatment where full attention during all phases is paid to proper stress distribution."

There are several etiologies that are believed to be major contributors to implant failure (7) and they include: (i) impaired healing ability of the host bone site; (ii) disruption of a weak bone-to-implant interface; (iii) infection in situations following complicated surgery; (iv) lack of primary stability following implant placement; (v) the application of loading forces before the biologic environment is capable of withstanding the force; and (vi) overloading of a successfully integrated implant. The possible factors that may be associated with the etiology of overload have been extensively reviewed (7).

A comprehensive review of the literature up to 2007 examined biologic complications and failing implants. It was determined that the major biologic factors associated with implant loss were infection, impaired healing, and overload (8).

The treatment provider should ensure that patients understand the various, well-known factors that enhance success and create complications before making an informed decision. Care should be taken to include the amount of time that specific procedures will take and the estimated longevity of one treatment option compared to another.

Since the causes, prevention, and management of prosthetic-related implant complications have not been subjected to scientific scrutiny through clinical studies, the views contained in this chapter represent the opinions and observations of the authors as well as the

thoughts of other authors who have published articles about dental implant complications referenced in this chapter.

This chapter will discuss in detail prosthetic-related dental implant complications, their etiology, prevention, and treatment.

The common prosthetic complications associated with dental implants could be classified as mechanical, phonetic, esthetic, and biologic complications.

Mechanical complications

Complications caused by unfavorable implant placement (poor angulation)

Etiology

Improper implant location and/or angulation can be due to a lack of bone in the preferred location for the implant owing to anatomic deformation, bone resorption, disease, or trauma. It can also occur because of a lack of planning, failure to follow the locations and angulations identified by the surgical template, or inadequate surgical technique.

Prevention and treatment

Moderate angulation of the implant in the bone can be corrected by use of a prefabricated angled abutment or by fabricating a custom abutment (Fig. 10.1a–h). This process adequately compensates for many accentuated implant angulations. However, if the implant will also be located lingual to the desired position (often due to facial bone resorption), bone grafting may be necessary to provide the added facial bone dimension so that proper faciolingual implant positioning can be achieved (Fig. 10.2a–e). Grafting also provides a volume of bone that may permit the implant to be placed with lesser angulation, thereby avoiding angled loading of the restoration relative to the long axis of the implant. It has been proposed that implant angulation should be less than 25 degrees to limit shear forces generated in the bone (9). When there is a lack of hard and/or soft tissue in the desired implant location, the deficient sites should be augmented either before or concurrently with implant placement to avoid compromising the final prosthodontic result (10).

Preoperative treatment planning includes determining whether an implant can be placed in an ideal position or whether a grafting procedure is required initially. This determination is usually accomplished by forming diagnostic wax patterns on a cast or diagnostically arranging prosthetic teeth on a cast. Using the desired tooth positions, a radiographic template can be fabricated and a computer axial tomographic (CAT) or a cone beam computerized tomographic (CBCT) scan taken to determine whether there is sufficient bone located apical to the desired tooth positions. A surgical template can also be fabricated that identifies and clearly approximates the angle and position of the implant in available bone. The template is then used during surgery to guide the implant placement process. The entire implant surgical process, from initial drilling to implant placement, must be continuously verified with the aid of the surgical template and sometimes even radiographs taken during the procedure to prevent involuntary misalignment of the implant.

Postoperatively, it may be determined that the implant is in a suboptimal position. If it is determined that the implant cannot be functionally or esthetically restored in its existing location, the implant can be left unexposed beneath the soft tissue and not uncovered, or it can be uncovered but not placed into function. However, if it is in a strategic position or is needed for the support and/or retention of a single crown, fixed partial denture, or complete arch prosthesis, it will need to be removed and another implant placed in a more appropriate position (Fig. 10.3). A trephine bur has been the traditional method used to remove the implant (Fig. 10.4a–l).

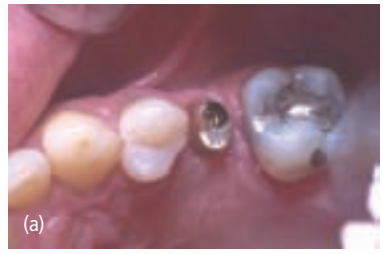
Complication attributable to the prosthesis: overdenture attachment complications and need for relines

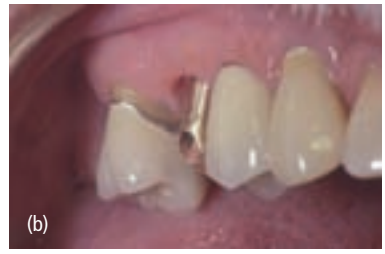
Etiology

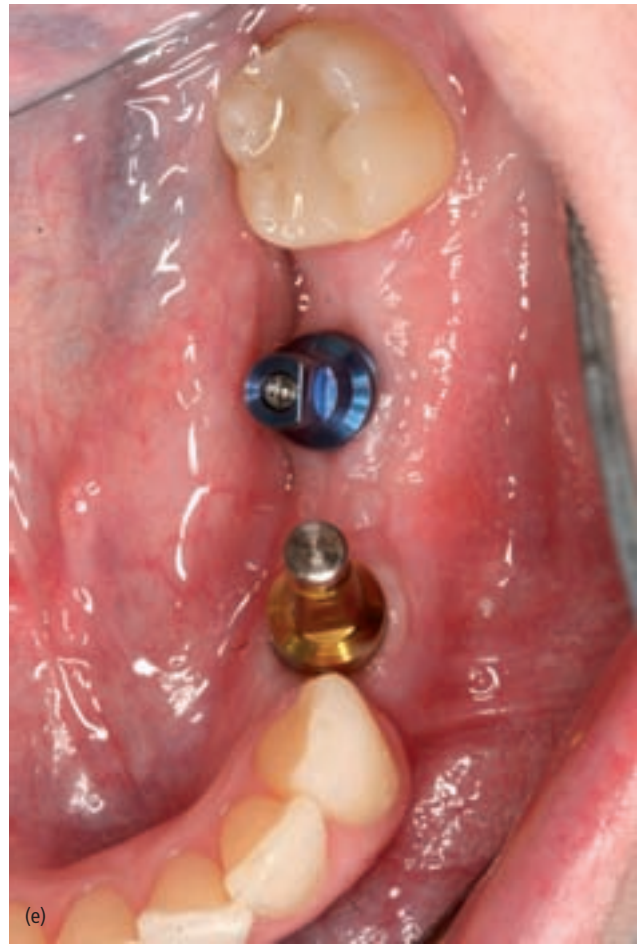
All implant overdenture attachments lose their retentiveness as wear occurs. When there is a lack of simultaneous contact of the attachments with the implants and the prosthesis base with the residual ridge, more stress is placed on the attachments and they lose their retentiveness more frequently. In addition, some patients have rigorous chewing habits and/or parafunctional activities and this supplements the significant forces already placed on the attachments, causing them to lose their retentiveness. The same factors cause overdenture attachments to fracture, which then need to be replaced.

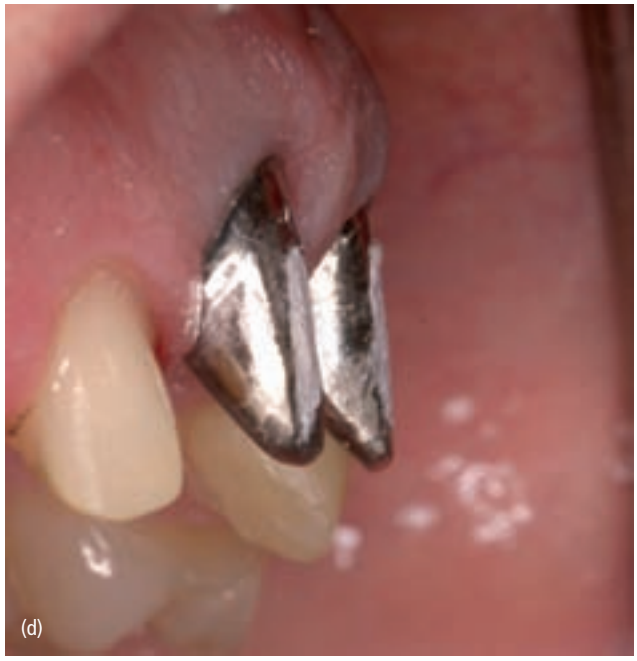
All prostheses need to be relined as changes usually occur in the residual ridges. The period of time it takes for bone resorption to progress to a degree where a reline is indicated varies between patients. The timing has also been attributed to the length of time the patient has been edentulous, with more change occurring in the early years following tooth loss.

When two implants were placed into the anterior aspect of edentulous mandibles and implant overdentures fabricated for patients who had been edentulous for less than 10 years, the patients exhibited greater annual posterior ridge resorption than complete denture patients (11). However, this increased rate of resorption









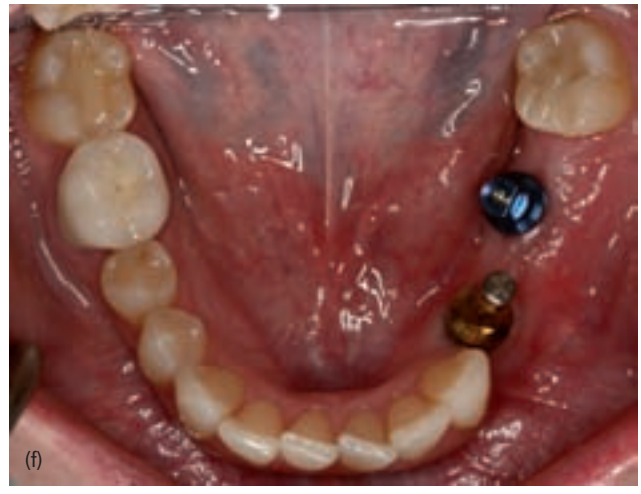
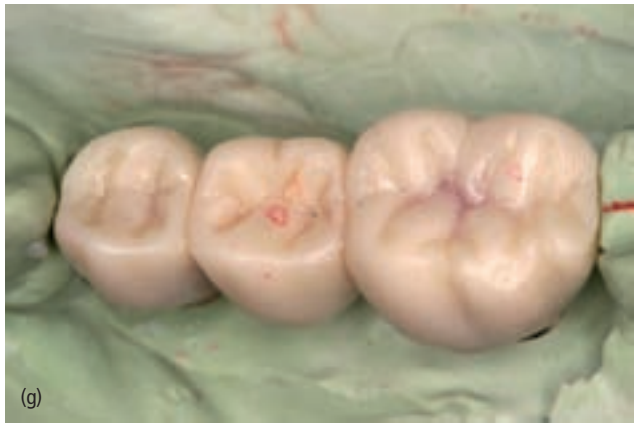


Fig. 10.1 (a) Occlusal view of custom abutment attached to the implant. Note the facially located access hole to the abutment screw that identifies the long axis inclination of the screw and therefore the implant. (b) Facial view of the custom abutment. The facial access hole is readily visible. (c) Impression copings on maxillary implants showing the facial angulation of the implants. (d) View showing the utilization of cast custom abutments to achieve a favorable esthetic prognosis. (e) View showing impression copings on implants placed divergent to each other.



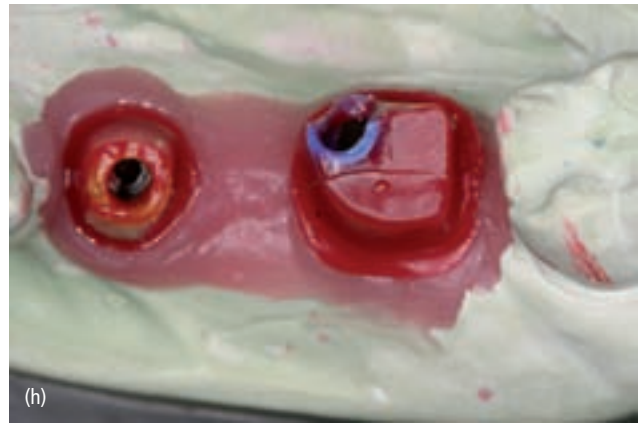
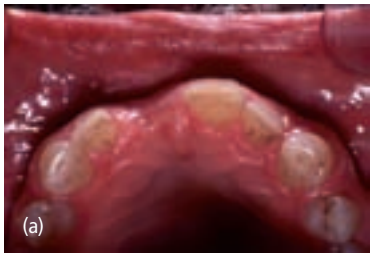
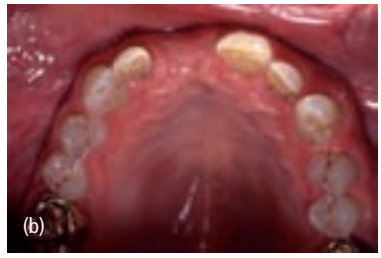
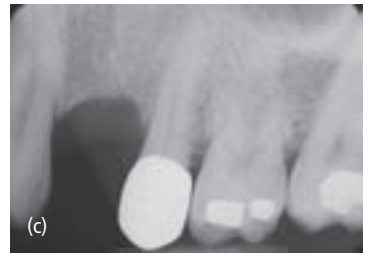
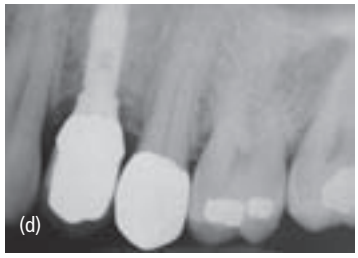


Fig. 10.1 ***(cont'd)*** (f) Occlusal view of impression copings. Note also the lingual location of distal implant. (g) A diagnostic wax pattern is fabricated to determine the contours that can be achieved for the final prosthesis. (h) The pattern for the custom abutments. Note the mesiolingual location of the occlusal screw access hole on the distal implant. A fixed partial prosthesis will be cemented over the custom abutments. (e–h: Courtesy of Dr V. Meserkhani.)









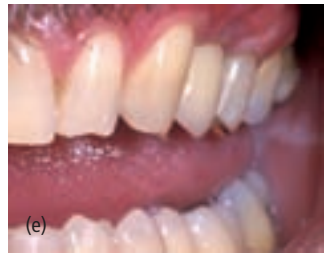


Fig. 10.2 (a) Pretreatment incisal view of the edentulous area. Note the facial bony defect. (b) Incisal view of the edentulous area following bone grafting. Note that there has been an increase in the facial thickness of the ridge. (c) Pretreatment radiograph of a large bony defect present where the maxillary first premolar has been extracted. (d) Bone grafting was performed and subsequently an implant was placed. (e) The first premolar crown appears normal in height and facial positioning because the bony defect was grafted before implant placement.

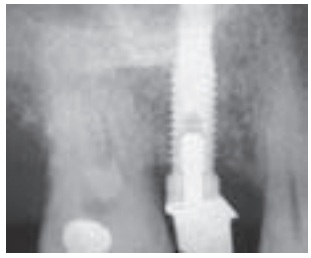


Fig. 10.3 The implant was placed distally and an attempt was made to fabricate a custom abutment that would correct the misalignment. However, the implant is located so far distally that the cervical aspect of the abutment is located beneath the proximal contact area of the molar. This location will prevent a crown from being seated over the abutment and would also produce a substantial anterior cantilever on the single crown. The implant needs to be removed and replaced with one located at the mesiodistal center of the edentulous area.

was not observed in patients who were edentulous for periods greater than 10 years (11). These findings indicate that there will be a greater need for relines in patient: who have been edentulous for less than 10 years.

Patients with parafunctional habits place heavy occlusal forces on the overdenture which are then transferred to the residual ridge, thereby increasing the bone resorption and the need for relines. In addition, patients with implants develop higher occlusal forces than complete denture patients (12–14). The ability to chew with greater rigor is one of the benefits of an implant-supported or retained prosthesis and therefore it is likely that implant overdentures that have a larger area of residual ridge coverage posteriorly will need relines.

Prevention and treatment

Achieving simultaneous contact between the overdenture retentive mechanism(s) and the residual ridge promotes uniform stress distribution and helps slow the

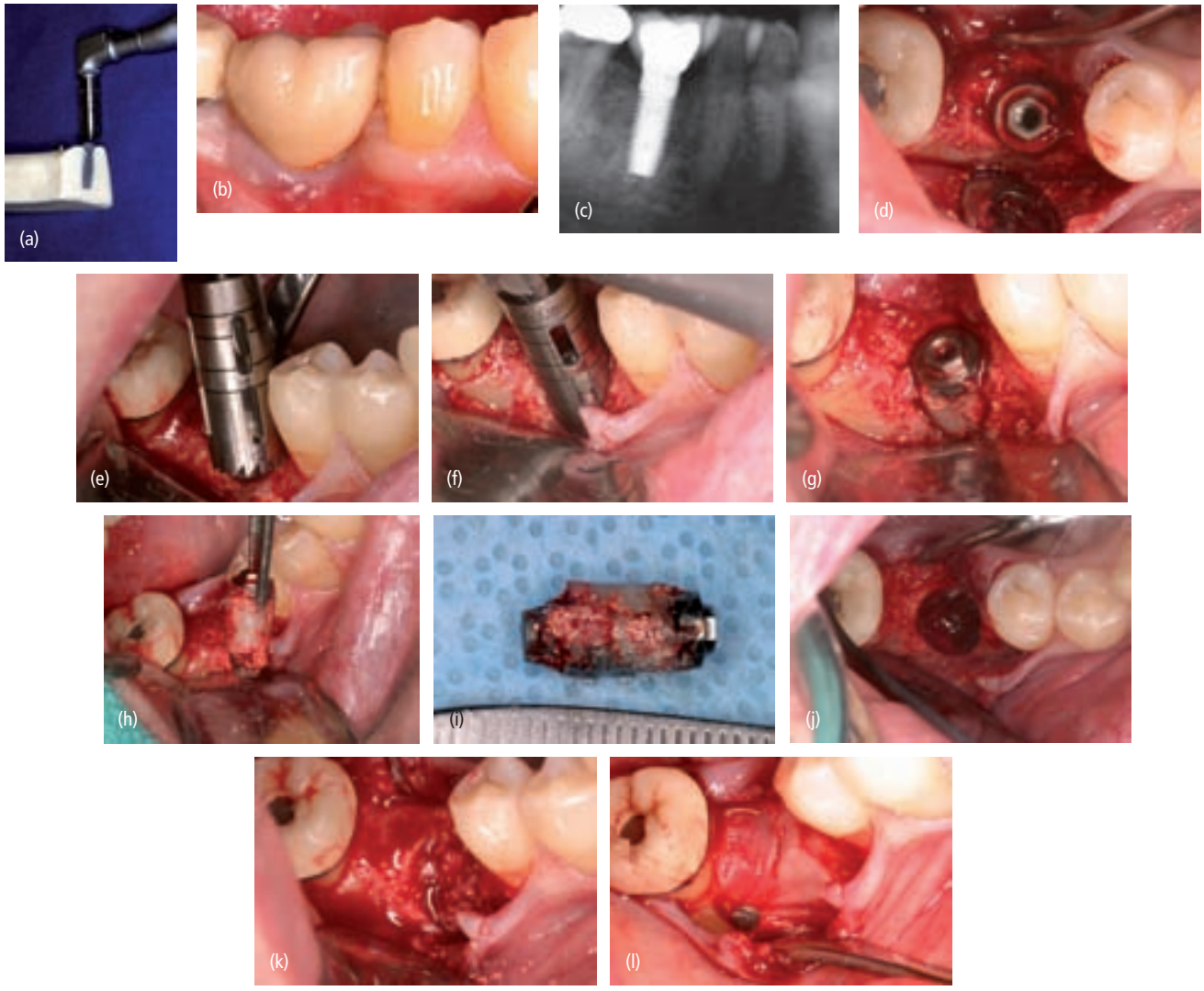


Fig. 10.4 (a) A trephine bur is located above an implant in a simulated jaw. The trephine bur is a hollow cylinder with cutting points located on the end of the bur. It can be positioned over the implant and used to remove bone circumferentially around the perimeter of the implant, thereby permitting removal of the implant while removing as little bone as possible. (b) Facial view of an implant single crown. The patient has persistent pain associated with the implant which has not subsided. The implant needs to be removed. (c) Periapical radiograph of the implant that appears normal. (d) The crown has been removed and a flap reflected to expose the implant. (e) The trephine bur that will be used to remove a core of bone that includes the implant. (f) The trephine bur surrounds the implant and is being used to create a circular cut around the implant to the full length of the implant. (g) The trephine cut has been completed. A core of bone that includes the implant has been isolated. The only bony holding for the implant is at the apical end of the core. An instrument will be placed around the core and used to fracture the apical segment of bone. (h) The bone core with implant is being removed. (i) The implant and thin layer of attached bone located on the surgical tray after removal. The implant was placed into grafted bone and remnants of the granular graft material are visible in the core of bone surrounding the implant. (j) An occlusal view of the osteotomy present after implant removal. (k) Graft material (combination of allograft and xenograft) has been placed into the osteotomy. (l) A membrane has been placed over the area and tacked in position.

residual ridge resorption process that leads to the need for relines.

With patients who have high functional expectations from their prosthesis or who have exhibited heavy occlusal forces on their previous complete dentures (as evidenced by prosthetic tooth wear), it is advisable to increase the number of implants placed and also increase the number of retentive mechanisms present (Fig. 10.5a, b). In this manner, the forces can be shared by multiple attachments, decreasing the need for adjustment and replacement. In addition, more of the residual ridge area will be covered by implants and the associated retentive devices, decreasing the area of residual ridge that is contacted by the prosthesis base.

Implant overdentures should be designed so they promote horizontal prosthesis stability and provide vertical resistance to dislodgment. Optimal horizontal stability is provided by milled bars and corresponding metal superstructures that are incorporated into the overdenture (Fig. 10.6a–c). Vertical resistance to displace-

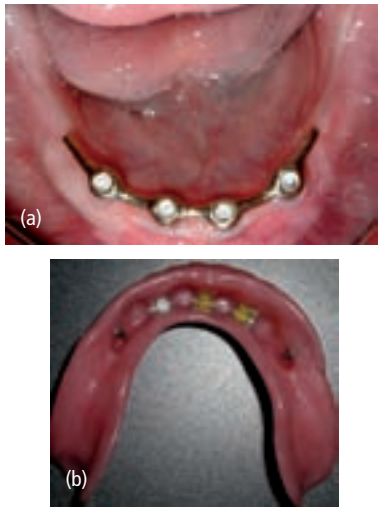


Fig. 10.5 (a) Occlusal view of multiple bars connecting four implants. Note the distally cantilevered bars. (b) The overdenture contains multiple anteriorly located clips and two sliding pins that provide retention and support. (Courtesy of Dr T. Daher.)

ment is optimized through the use of horizontal plunger-type attachments or hinge attachments (Fig. 10.7a–e).

The increased bone resorption recorded in patients with implant overdentures who have been edentulous for shorter periods led a group of authors to propose that implant overdentures should be cautiously evaluated in younger patients (11). Another author, in a literature review, suggests that overdentures may not be the treatment of choice in younger patients or those who have been edentulous for shorter periods. A mandibular implant-supported fixed complete denture may provide better bone preservation than an implant overdenture for these patients (15).

Prosthesis fractures

Etiology

Fractures of implant overdentures and resin prosthesis bases occur because of the increased force exerted by patients who have implants, by the stress concentration produced when retentive mechanisms are incorporated in prostheses, and by a resin thickness that is not sufficient to resist the forces placed on the prosthesis. Even adequately thick resin and metal can fatigue over time and fail.

Opposing conventional complete dentures may fracture because the occlusal forces are greater now that

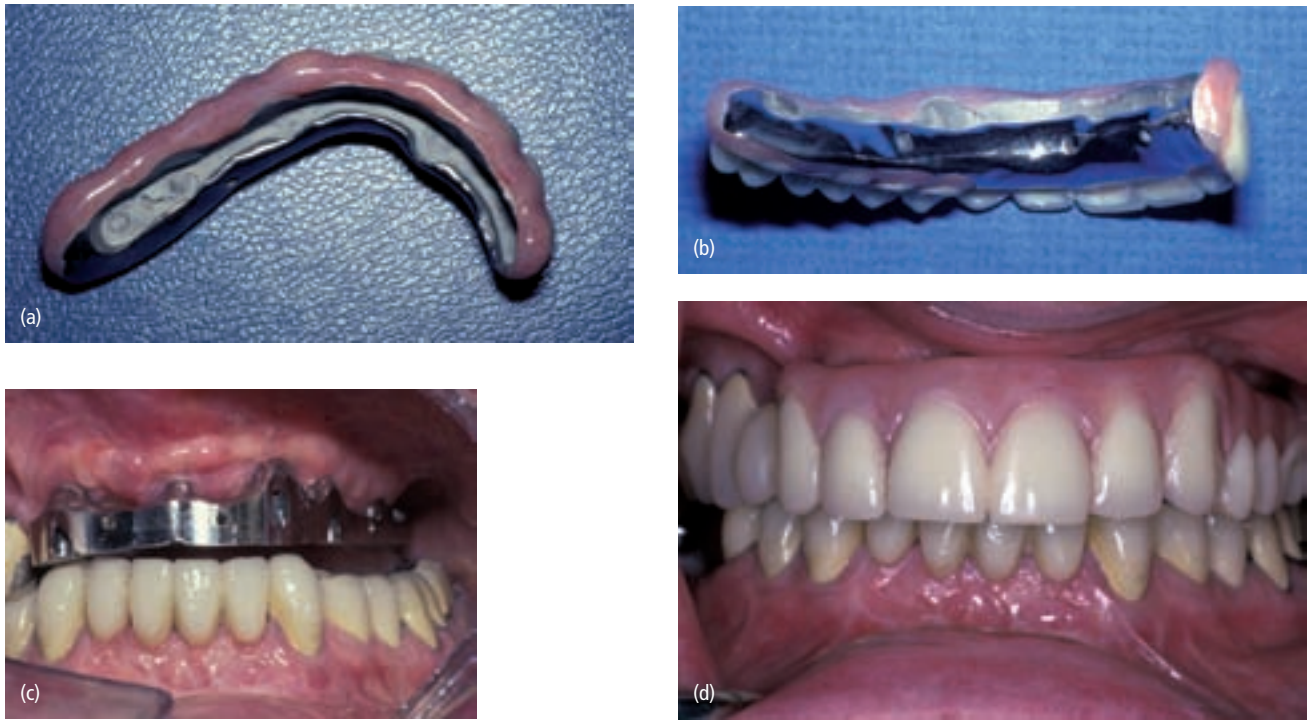


Fig. 10.6 (a) Occlusal view of the intaglio surface of a maxillary implant-supported prosthesis that will seat over a custom cast milled bar. (b) Lingual view of the maxillary implant-supported prosthesis. Note the threaded holes in the metal framework for the lingual screws. (c) Frontal view of the milled bar. The close contact between the milled bar substructure and the maxillary prosthesis (superstructure) provides support and stability. The primary retention is provided by the lingual screws that will engage the prosthesis and the substructure.

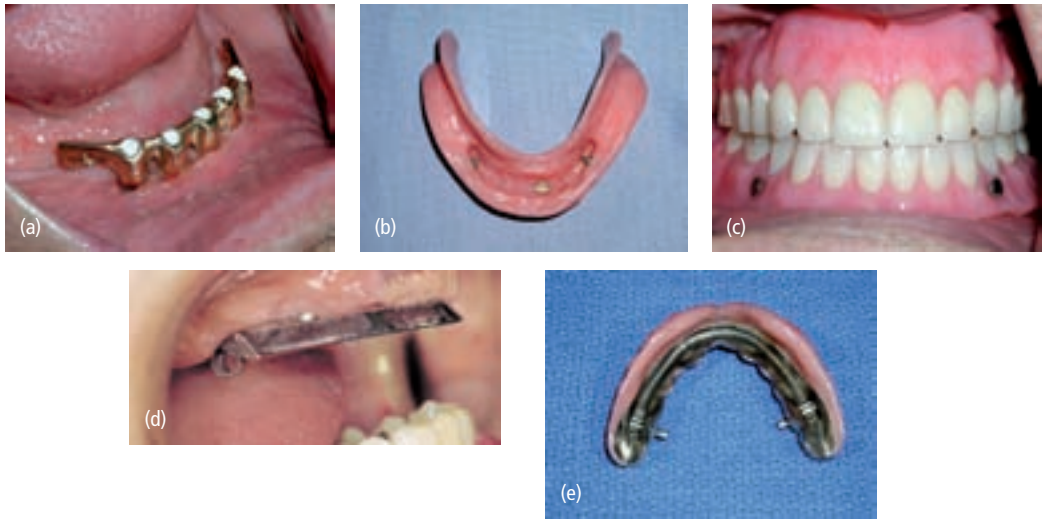


Fig. 10.7 (a) Five implants have been connected with bars. There are cantilevered bars located distal to the implants on each side with holes that accept sliding rods from the attachment (Locking Pin Snap System; Bredent USA, Southern Diversified Industries, Miami, FL, USA) in the overdenture. (b) An intaglio view of the overdenture shows a retentive clip located anteriorly and the two sliding rods located posteriorly. The rod slides in and out of the prosthesis in a faciolingual direction. (c) Frontal view of the mandibular overdenture and maxillary complete denture. The sliding rods have an external rim that the patient uses to disengage the rods and remove the denture. A fingernail is placed under the rim of each rod and the rod is pulled in a facial direction, thereby disengaging the rods from the holes in the bars and releasing the denture. (d) Lateral view of the cast bar. Note that there is approximately a 20° facial inclination and an anterior cervical undercut. Posteriorly, the circular receptacle for the sliding retentive mechanism (Mk I Universal Attachments, Sande, Germany) is visible. (e) Intaglio surface of the prosthesis. While a facial flange is present, there is minimal palatal bulk. The posterior retentive devices protrude lingually when they are not engaged. (a–c: Courtesy of Dr T. Daher; d, e: courtesy of Dr R. M. Sullivan.)

implants are present in the opposing arch. In addition, the previously adequate resin thickness may not be sufficient to resist the heavier forces, particularly the resin thickness in the midline of opposing maxillary complete dentures.

Metal framework fractures of implant fixed complete dentures (Fig. 10.8a–c) and fixed partial dentures occur because of inadequate metal thickness, porous cast metal, and porous and/or inadequate soldered connections.

Prevention and treatment

Preventing implant overdenture fractures and resin base fractures is best accomplished by maintaining an adequate resin thickness of at least 2 mm over retentive devices and underlying metal frameworks.

The presence of heavy occlusal forces may indicate the need for incorporation of a metal framework (Fig. 10.9) or a woven or fiberglass-impregnated mesh into the prosthesis.

Preventing opposing prosthesis fracture is best accomplished through adequate resin thickness at the midline of opposing maxillary complete dentures and in the resin surrounding labial frenal notches (Fig. 10.10a). The incorporation of metal palates, metal reinforcing meshes, or woven or fiberglass-impregnated meshes may be necessary for some patients.

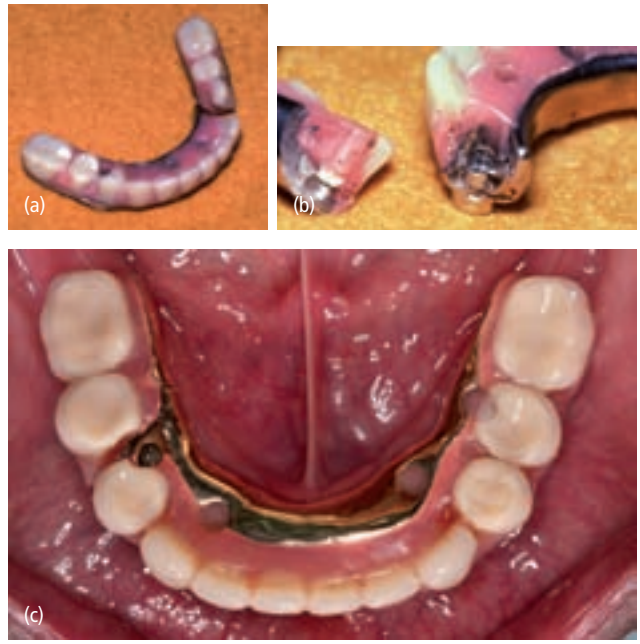


Fig. 10.8 (a) Fractured mandibular fixed complete denture. (b) Note the limited thickness of the metal casting and the porous quality of the casting. (c) Fracture on mandibular fixed complete denture clearly visible on the gold alloy framework as well. The fracture could be attributed to heavy occlusal forces (the opposing prosthesis was a maxillary fixed complete denture) and longer cantilever extension on the fractured side.

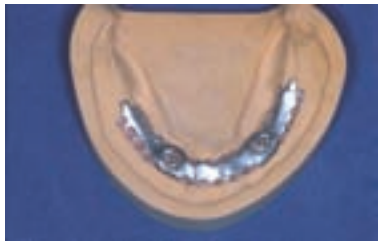


Fig. 10.9 A metal framework is seated on the cast. Note that the framework was designed in conjunction with the location of the two retentive mechanisms that will attach the overdenture to two implants. (Courtesy of Dr G. Bernal.)

When resin base fractures occur, the prosthesis should be repaired and the resin thickness increased, if possible. It may also be prudent to incorporate a metal mesh into the repair site.

Fractures of a fixed complete denture metal framework are best resolved by fabricating a new framework with thicker metal. Occasionally, it may be possible to remove overlying teeth/resin and solder the metal framework. Fractures of implant fixed partial denture frameworks require fabrication of a new prosthesis. Milled titanium computer-aided design–computer-aided manufacturing (CAD-CAM)-generated metal frameworks have similar strength and less potential for porosities. They offer improved precision since the variables that are encountered during a casting process are avoided (Fig. 10.10b).

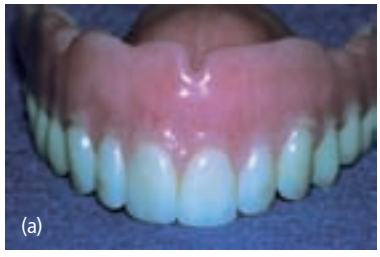


Fig. 10.10 (a) A new maxillary complete denture that will oppose a mandibular implant prosthesis. It has increased thickness around the frenal notch so the denture will be less likely to fracture from the increased occlusal forces that will be exerted. (b) A CAD-CAM titanium framework for a fixed complete denture.

When new prostheses are fabricated, any cantilevers present on the prosthesis should be carefully evaluated to determine whether they contributed to the fracture and whether they can be reduced or eliminated.

Screw loosening and fractures

Etiology

Most screw loosening occurred with early screw designs, owing to a lack of devices that could deliver a specified torque during screw tightening.

Screw loosening and/or fractures also occur when prostheses do not fit adequately. One study (16) evaluated the effect of vertical discrepancies between an implant fixed complete denture framework and the implants. Significant prosthetic screw instability was noted when there was both a 100 and a 175 mm discrepancy.

It has been proposed that prosthesis fit should be such that when a screw is tightened with a torque device, the screw should only rotate about a quarter of a turn (90 degrees) between firm hand tightening of the screw and achievement of the recommended torque level.

Heavy occlusal forces and cantilevers also contribute to screw loosening and fracture.

Prevention and treatment

Preventing screw loosening and fractures is best accomplished by ensuring screws are tightened using either a hand or electronic torque device and making sure prostheses fit properly. Research and manufacturing enhancements have resulted in surface coating and screw designs that improve fit, increase preload, and help prevent loosening.

Reducing prosthesis cantilevers, when possible, also helps prevent the loosening of screws and/or their fracture.

Aligning implants so they are centered beneath occluding surfaces and perpendicular to the occlusal plane decreases the leverage that will be applied to the various metal components (Fig. 10.11a, b) and can aid in reducing the incidence of screw loosening and fracture.

When screws loosen, they can be retightened. If the screw has been in service for some time, it is advisable to replace the screw with a new one.

Occasionally, when a crown has been cemented over an abutment, the abutment screw can loosen and there is no access to the abutment screw for the purpose of retightening. For this reason, some practitioners use lingual retaining screws rather than cementation of the crown to permit future retrieval of the crown (Fig. 10.11c–f) (17). The use of lingual retaining screws may be prudent when the likelihood of screw loosening or fracture is increased owing to heavy occlusal forces or

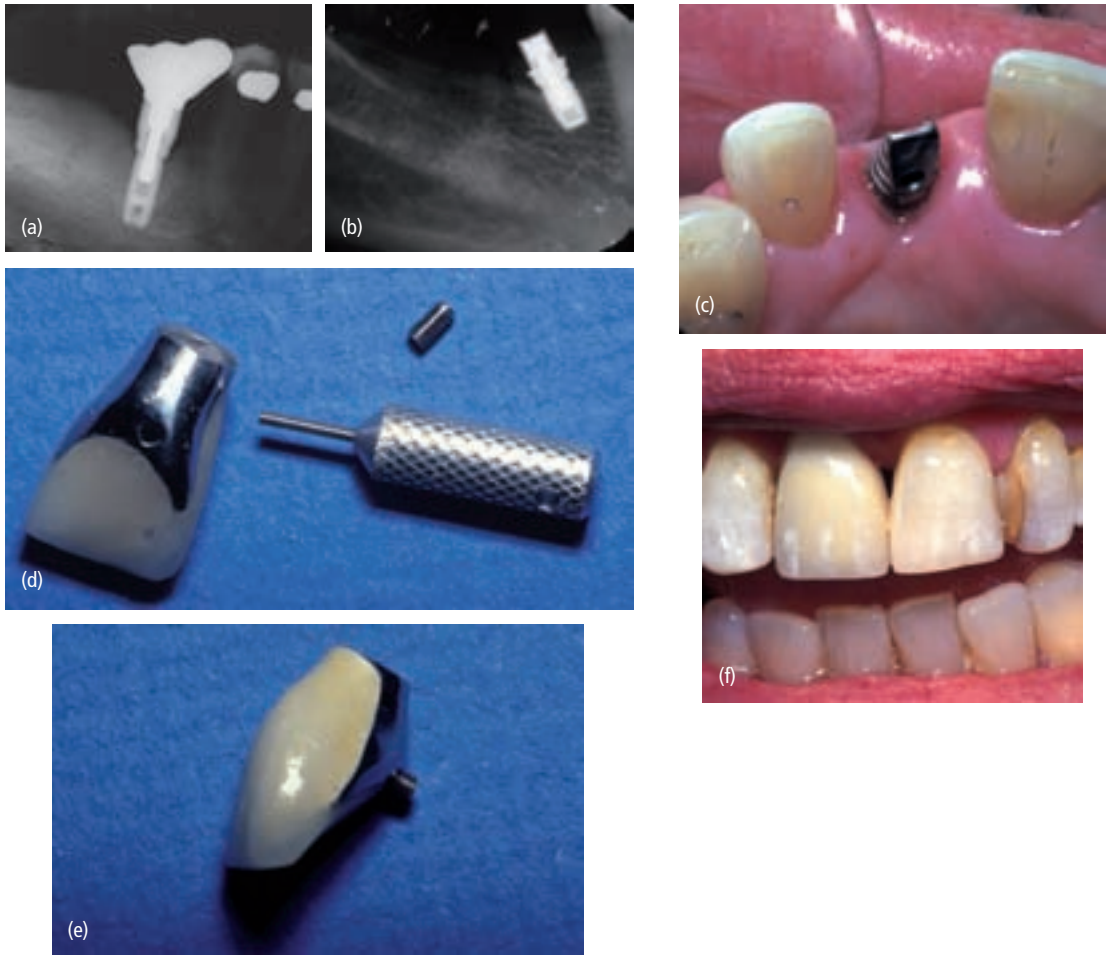


Fig. 10.11 (a) The first molar implant has been positioned in the bone so it is slightly out of alignment with the ideal relationship (perpendicular to the occlusal plane). (b) A short implant placed with a distal inclination that is substantially inclined relative to the occlusal plane. (c) Lingual view of a custom abutment showing the threaded screw hole. (d) View of implant crown with the lingual screw and the driver used to engage and tighten the screw. (e) View showing the lingual screw engaging the crown partially before seating on the custom abutment. (f) Maxillary implant crown seated with lingual screw engaged and tightened for retention to the custom abutment. This will allow for easier and less damaging removal of the crown if required in the future.

extensive cantilevers on occlusal surfaces that are not centered over the implants.

When an abutment screw has come loose, methods have been devised for removing the overlying crowns or fixed partial dentures (18–20). One method involves fabricating the crowns with threaded tubes designed for small screws that can be turned and used to unseat the crown via contact between the end of the screw and the underlying abutment (18). A crown can also be fabricated with a deliberate cylindrical hole in the crown and a slot in the abutment that allows a special instrument to be inserted into the crown hole and rotated until the crown loosens (19). Another removal method uses a vacuum-formed template that serves as a guide for drilling a hole through a crown or prosthesis at the proper location so the screw can be accessed (20).

Digital images of screw access hole locations in abutments are valuable resources should an abutment screw come loose beneath a cemented crown.

When screws fracture, it can be a challenge to remove the screw fragment. However, the design of many older screws was such that they did not incorporate frictional fit with the implant threads, thus permitting an explorer or other dental instrument to be used to manipulate the fragment slowly in a counterclockwise direction.

When a screw breaks at the top of its threaded section, it may be accessible to a dental instrument and the screw can be rotated counterclockwise until it can be grasped with an instrument and removed (Fig. 10.12a–m). When the fractured segment of a prosthesis retaining screw is located inside a prefabricated or custom abutment, the abutment can be removed if necessary to facilitate removal of the fragment in the laboratory.

Methods of removing screw fragments that cannot be rotated with a hand instrument or grasped by a hand instrument have included running a drill in reverse to grasp and remove the fragment, drilling into the screw fragment so it can be grasped, grinding a slot into the top

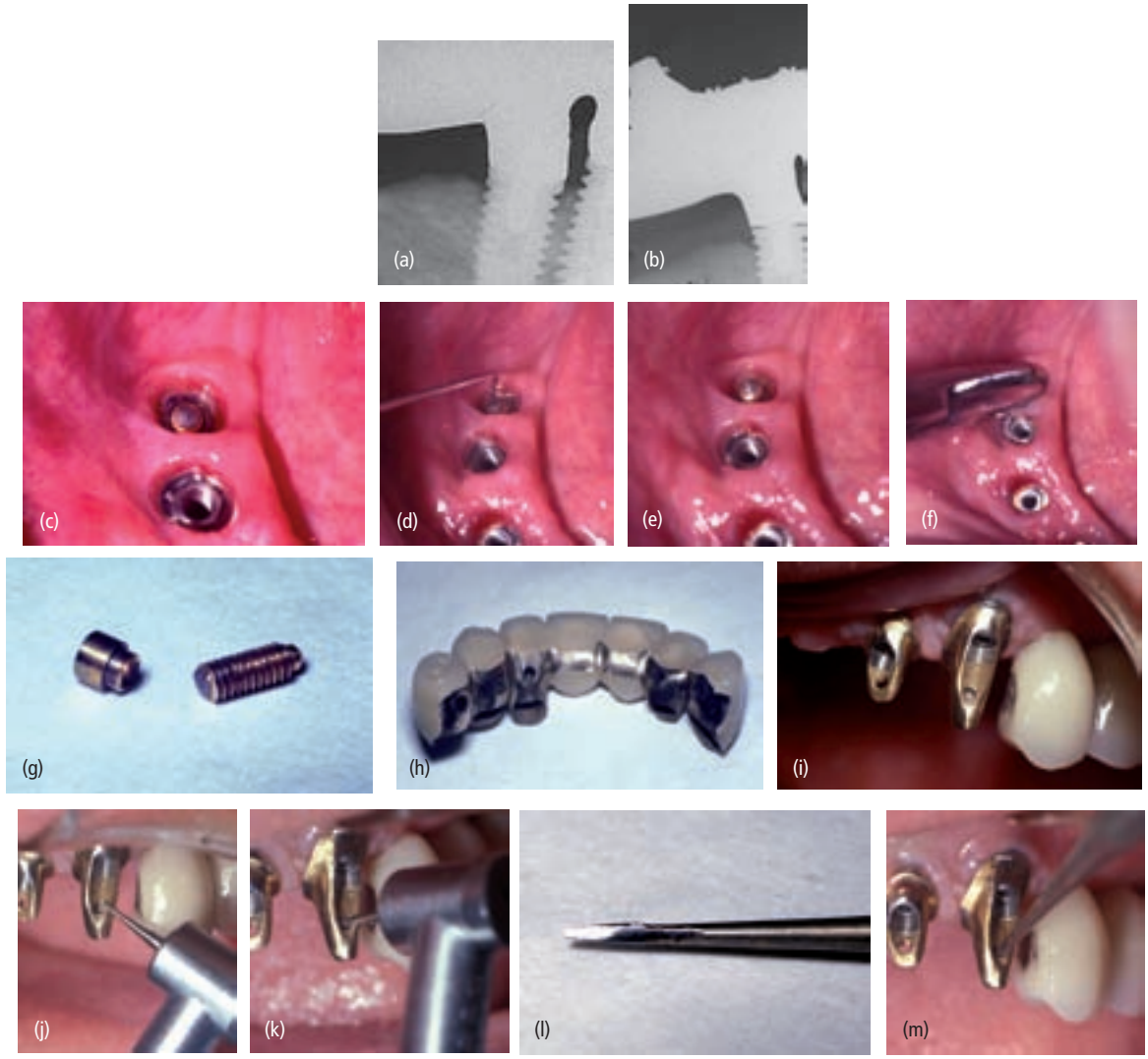


Fig. 10.12 (a) Postplacement radiograph of the distal implant (one of five) supporting a mandibular implant fixed complete denture. (b) A routine radiograph detected a space between the implant and prosthesis, indicative of a possible loose or fractured screw. (c) Removal of the prosthesis revealed a fractured abutment screw. (d) Use of an explorer to reverse the screw. (e) The screw has been reversed by the screwdriver to the point it projects above the implant. (f) The screw can now be grasped by a hemostat to complete removal of the fragment. (g) The fractured screw fragments after removal. (h) Lingual retentive screws were used in this maxillary anterior prosthesis to aid in future retrievability should a mechanical complication occur. The patient has previously fractured a cemented prosthesis, requiring remaking of the prosthesis. (i) The lingual retentive screw into the canine abutment fractured after about 1 year. (j) A slow-speed round bur will be used to grind a slot into the remaining screw fragment so it can be removed. (k) The round bur being used. (l) A hand instrument has been custom shaped so that it will fit into the slot ground into the screw fragment. (m) The modified hand instrument being used to remove the screw fragment.

of the screw fragment and modifying some instrument so it fits into the slot and the fragment can thereby be unscrewed (21).

When a fractured abutment screw fragment is located inside an implant, there are manufactured retrieval instruments (Fig. 10.13a–f) that can aid in the process. Screw taps are also manufactured to refresh implant threads should they become disturbed during the screw fragment removal (Fig. 10.13g).

Complication arising from host factors and implant overload: implant fractures

Etiology

Implant fractures have occurred as a result of heavy occlusal forces (Fig. 10.14a), the use of standard diameter implants in situations where there are heavy forces (such as molars) (Fig. 10.14b), and the presence of substantial cantilevers on the crown or prosthesis. Fractures have

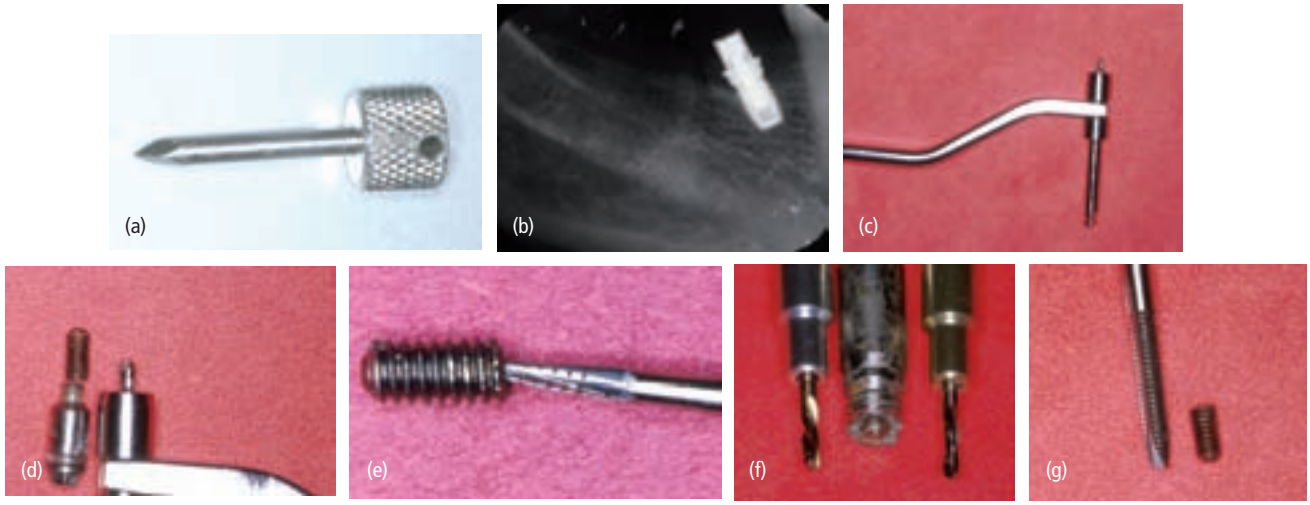


Fig. 10.13 (a) A hand instrument with a pointed tip that can be used to engage fractured screws inside an implant. (b) The instrument shown in (a) being used to remove a screw. (c) A screw removal instrument that consists of a handle, a metal sleeve that fits over the top of the implant, and a drill that fits inside the metal sleeve. (d) Close-up view of the metal sleeve and bur. (e) A tapered carbide bur that was used in reverse to remove this fractured abutment screw. (f) Drills that have the cutting blades oriented in a reverse direction to aid in the removal of fractured screws. (g) A screw tap located alongside a fractured abutment screw. (Courtesy of Dr R. Yanase.)

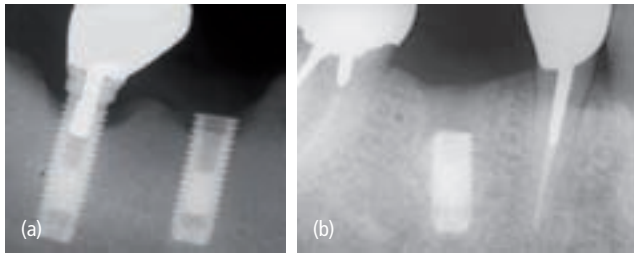


Fig. 10.14 (a) The mandibular implant fractured owing to heavy occlusal forces. (b) Periapical radiograph of the fractured implant. The fracture occurred about 3 months after cementation of the crown.

also occurred through improper surgical placement of root form implants (Fig. 10.15a–e). When excessive force is used to insert an implant as a self-tapping device into dense bone, the implant or the components used to place the implant can fracture.

Prevention and treatment

During surgical planning and placement, the bone density should be carefully assessed to determine whether bone tapping is needed or a self-tapping protocol can be followed.

During prosthodontic planning, implant fracture is best avoided by the following means: (i) limiting the extent of any cantilevers; (ii) using an adequate number

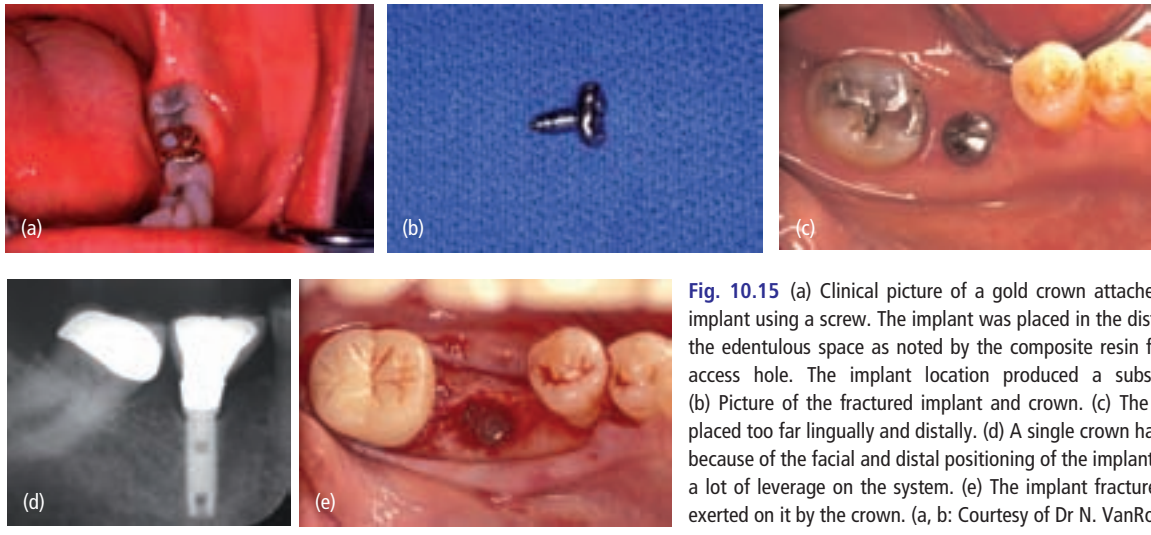


Fig. 10.15 (a) Clinical picture of a gold crown attached to a first molar implant using a screw. The implant was placed in the distolingual aspect of the edentulous space as noted by the composite resin filling in the screw access hole. The implant location produced a substantial cantilever. (b) Picture of the fractured implant and crown. (c) The implant has been placed too far lingually and distally. (d) A single crown has been placed and because of the facial and distal positioning of the implant, the crown places a lot of leverage on the system. (e) The implant fractured from the forces exerted on it by the crown. (a, b: Courtesy of Dr N. VanRoekel.)

of implants; (iii) creating a staggered alignment of the implants for a fixed partial denture (not placing them in a straight line); (iv) creating an appropriate symmetric curved arrangement of the implants for an implant fixed complete denture and (v) producing at least 10 mm of anteroposterior dimension to the curved arrangement of the implants for a fixed complete denture; and (vi) using wider diameter implants for the replacement of single molars.

Cantilever extensions for mandibular implant fixed complete dentures should not exceed one-and-a-half times to twice the anteroposterior distance between the implants and should not be greater than the anteroposterior dimension in the maxilla (22). With posterior implant fixed partial dentures and implant single crowns, the maximum horizontal cantilever (distance the crown or prosthesis extends lateral to the implant) should not exceed the diameter of the implant (22). For anterior implant single crowns and fixed partial dentures, the maximum horizontal cantilever should not exceed twice the implant diameter (22).

When an implant fractures, there are trephine drills available that can be used to remove the implant (Fig. 10.16a–c). The trephine drill fits over the implant (the internal diameter of the trephine is just slightly larger than the diameter of the implant). The trephine drill removes a bony core that includes the fractured implant (Fig. 10.17). Other methods of implant removal include the use of a thin diamond or piezoelectric surgical tip to cut a channel around the implant so it can be removed using reverse torque. After the implant has been removed, a graft material and membrane barrier can be used to fill in the defect. The clinician can also choose to allow new bone formation eventually to fill the area without a graft being used. Following healing, another implant can be placed. It may also be possible immediately to place an implant with a larger diameter than the one removed with the trephine diamond drill or piezoelectric tip.

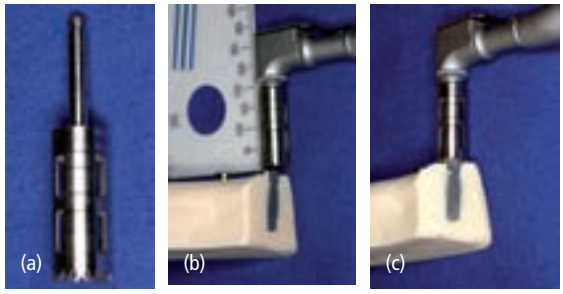


Fig. 10.16 (a) A trephine drill. Note the hollow cylindrical form with cutting blades at the end. (b) The trephine bur being aligned over an implant in a simulated jaw. A ruler is located next to the bur so the appropriate marking can be identified that corresponds to the length of the implant. In that way, the bur can be used to drill alongside the implant to the full length of the implant. (c) The trephine bur is oriented over the occlusal aspect of the implant. (b, c: Courtesy of Dr J. Lozada.)

Fig. 10.17 The appearance of an implant after it has been removed using a trephine bur. This is the fractured implant seen in Fig. 10.15(e). Note the small amount of bone still adhered to the implant. (Courtesy of Dr J. Lozada.)

Phonetic complications

Etiology

Studies have reported phonetic problems associated with fixed complete dentures, overdentures, and fixed partial dentures. The problems were more common in the resorbed anterior maxilla than elsewhere (Fig. 10.18a). Open spaces that allow the passage of air to occur in areas that were previously completely blocked by a conventional prosthesis can produce phonetic challenges for patients. Improper implant placement can also produce phonetic challenges (Fig. 10.18b).

Prevention and treatment

For completely edentulous patients, the effect of removing palatal resin and decreasing prosthesis bulk can often be determined by duplicating the wax trial denture and removing the resin to assess the effect of such changes. Patients usually adapt phonetically to modest changes in the form of a prosthesis, and natural speech patterns are reacquired over time.

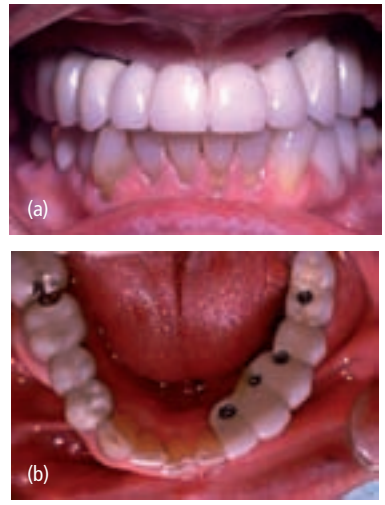


Fig. 10.18 (a) Maxillary fixed complete denture (metal–ceramic) supported by eight implants. The resorption of the maxilla necessitated lingual placement of the implants and it took the patient some time to acclimate phonetically. (b) The mandibular implants were placed too far lingually and created speech problems.

In situations where the resolution of a phonetic complication is delayed, it is advisable to make a palatogram over the palatal region of the cameo surface of the maxillary denture using poly (vinyl siloxane) impression material while the patient reads from a prepared text that covers most syllables and consonants (Fig. 10.19). An example of a prepared text that the patient reads from would be: "What is your slow toe doing in the yellow liquid on the shelf? Is it trying to judge or measure the temperature, change its color, or just reach out and touch something grand and glorious?" The denture can then be remade or resin added to the palate using the phonetically generated impression material contour as a guide.

Sometimes removable silicone obturators can be made that fit between the gingiva and framework to block air passage and improve speech. They can be removed for the completion of appropriate oral hygiene.

Esthetic complications

Etiology

Esthetic complications have been reported in conjunction with fixed complete dentures, fixed partial dentures, and single crowns. It has been stated that maxillary anterior esthetic complications are the most frequently observed difficulty in implant prosthodontics (23). Contour, shade, embrasure spaces, and gingival recession have been identified as sources of the esthetic challenges.

Other esthetic challenges have been related to malpositioning of implants (Fig. 10.20a, b) and bone resorption present before implant placement that prevents the ideal placement of implants and can produce open cervical embrasures between single crowns or the units of a fixed partial denture (Fig. 10.21).

Achieving ideal soft-tissue form and interdental papilla height can be a challenge when placing implants into highly visible edentulous areas. Interdental dark spaces may be present (Fig. 10.22a, b), the marginal tissue may be thicker than the gingival margin present around adjacent teeth (Fig. 10.23), the apical location of the soft-tissue margin may not be at the same height as adjacent or contralateral natural teeth (Fig. 10.24), interdental papillae may not possess the most desirable form or height (Figs 10.21–10.25), or recession of the soft tissue

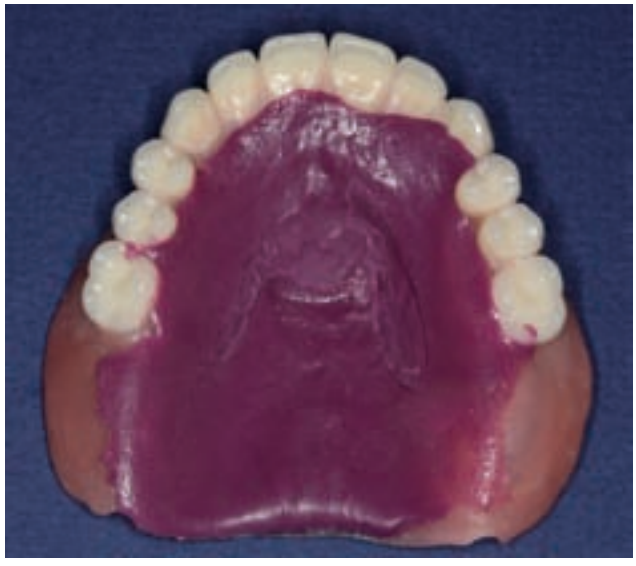


Fig. 10.19 Palatogram on maxillary record base.

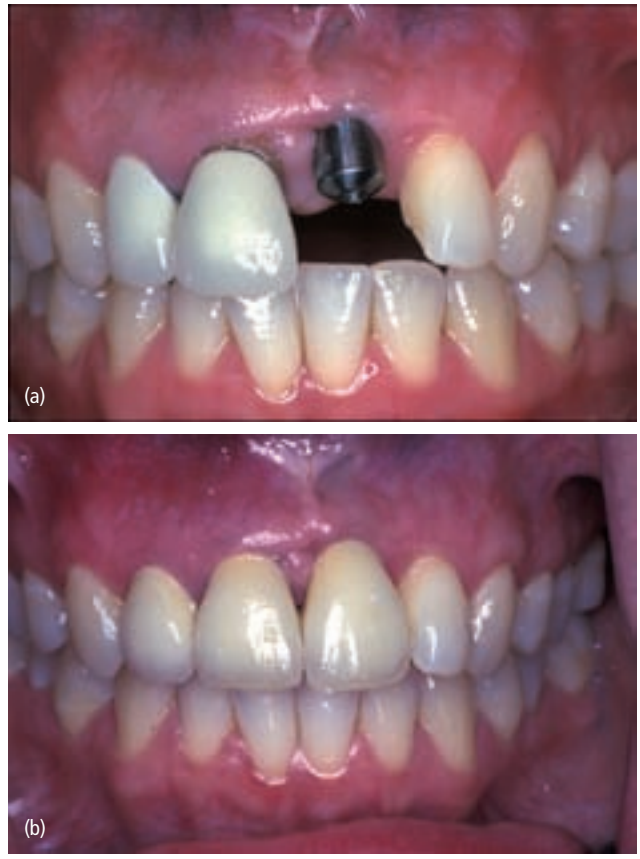


Fig. 10.20 (a) The central incisor implant was positioned too far facially. A custom abutment was made in an attempt to help compensate for the facial positioning. (b) The two adjacent crowns were also replaced in an attempt to achieve a favorable result.

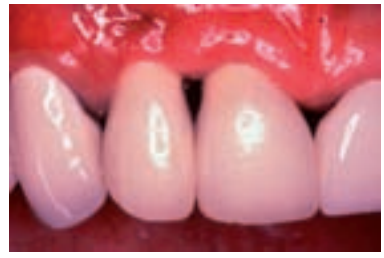


Fig. 10.21 Large interdental spaces are present following placement of multiple implants. (Courtesy of Dr J. Lozada.)

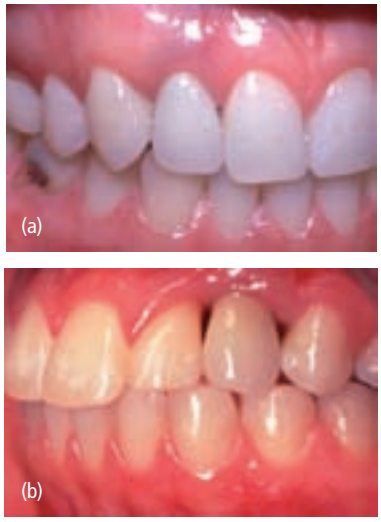


Fig. 10.22 (a) Facial view of a metal ceramic crown. There is a small dark space located below the mesial proximal contact that would not be visible if the interdental papilla completely filled the space. (b) An implant has been placed in the canine area where considerable ridge resorption and accompanying gingival recession has occurred. Relatively large dark spaces are present in the cervical embrasures of the implant crown. (Courtesy of Dr J. Lozada.)

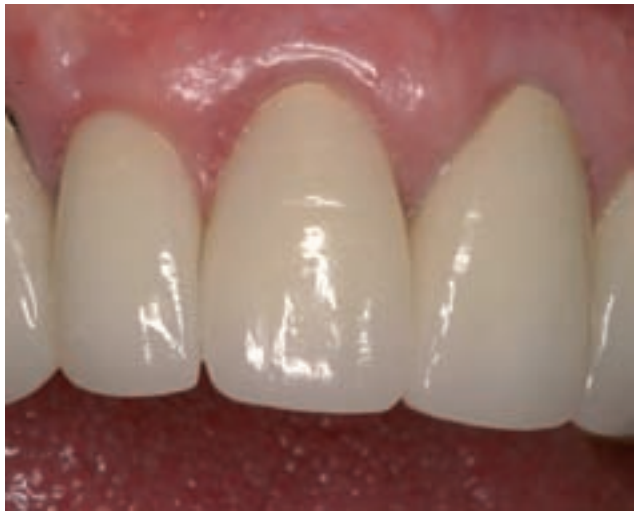


Fig. 10.23 The marginal tissues are thicker around the implant crowns.

may lead to crown length variations and/or exposed metal (Fig. 10.26a, b).

Placing an implant too far lingually may produce a crown with an abnormal facial cervical contour (Figs 10.1b and 10.27) or a crown where porcelain must overlap the facial soft tissue to create the desired cervical crown morphology (Fig. 10.28a–c). The overlapping makes oral hygiene more difficult and could present an esthetic liability should the soft-tissue position recede apically. In some situations, it may be necessary to have a substantial amount of the crown overlapping (Fig. 10.29a–c) the facial soft tissue (similar to what occurs with certain fixed partial denture pontics) or the crown will assume a form with significant cervical deficiencies or inadequate emergence profile (Figs 10.30a, b and 10.31a, b).

Placing an implant too far facially creates substantial esthetic challenges that often cannot be overcome (Fig. 10.20a, b).

Gingival recession can cause esthetic challenges. Recession was measured in a 1-year prospective study (24), which indicated that about 1 mm of recession can generally be expected following abutment connection surgery. Eighty percent of the buccal sites exhibited recession. Since most of the recession occurred within the first 3 months, the authors proposed waiting 3 months after abutment connection surgery before making the definitive impression (24).

Prevention and treatment

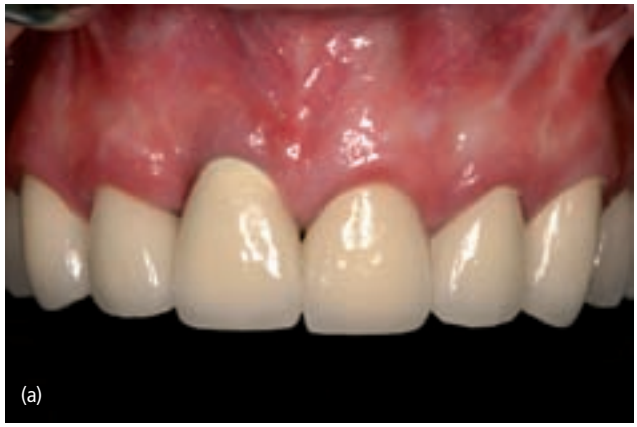
In esthetically critical locations, it is important to remember that the placement of implants is a critical process and it may not be possible to always place them in the most ideal location. When bone dimensions permit, implants should be placed slightly facial to the faciolingual center of the edentulous area (Fig. 10.1a).

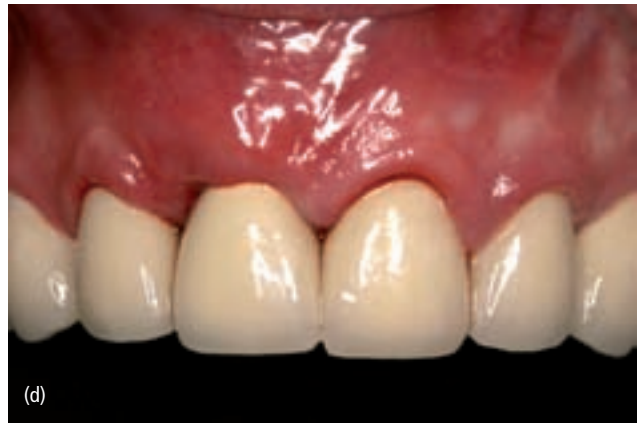
When an implant is placed lingual to the faciolingual center of the adjacent teeth, it may be necessary to have the crown overlap the facial soft tissue (similar to what occurs with certain fixed partial denture pontics) to achieve a normal cervical form. Alternately, a horizontally submerged ovate form (similar to an ovate pontic) can be developed (similar to an ovate pontic form) that supports the soft tissue in a more esthetic fashion (Fig. 10.32a–d).

When an implant is placed too far facially, it may have to be removed, bone fill allowed to occur, and another implant subsequently placed in a more favorable position. Implant removal is most commonly accomplished using trephine instruments (Figs 10.16a–c and 10.17).

Proper incisocervical/occlusocervical positioning of implants promotes the development of transitional contours and normal emergence profile. The incisocervical/occlusocervical location of the implant is largely determined by the location of existing bone (Fig. 10.33a–c) and the esthetic need to transition from a smaller diameter round form to a larger diameter form with a different geometric perimeter. Typically, implants have been placed slightly apical to the cementoenamel junction of adjacent teeth to permit the required changes in morphology to occur gradually (Fig. 10.34).

When bone is present at the proper height interproximally, the soft tissue can fill in small spaces over time (Fig. 10.35a, b). It is apparent that the distance from the soft-tissue crest to the bone is important in maintaining the presence of papillae between natural teeth and implants. One study (25) involved 27 single implants





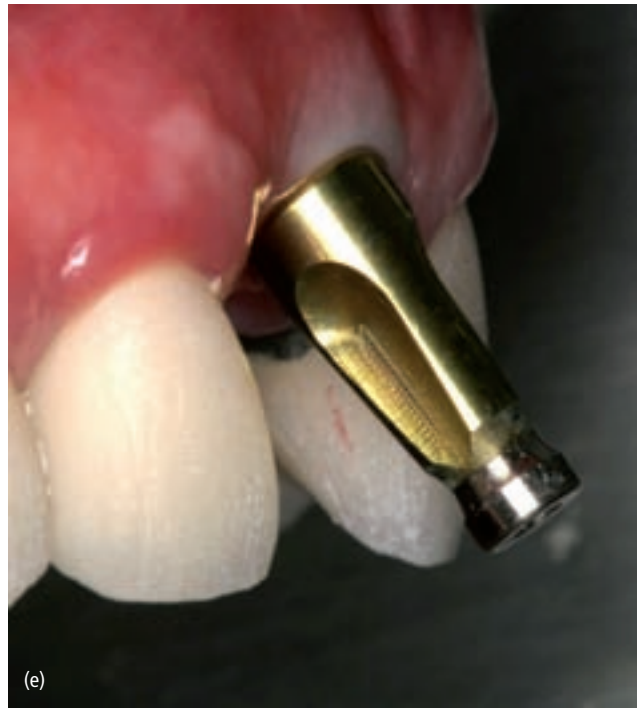


Fig. 10.24 (a) View showing the presence of apically located gingival margin around an implant crown for the maxillary right central incisor. (b) The metal ceramic crown was thinned as much as possible at the facial cervical area in an attempt to achieve an optimal tissue response. (c) View of the custom abutment on the implant replica and the metal ceramic crown. Note the thin metal margin and lack of ceramic in the subgingival area of the crown. (d) Surgical soft-tissue augmentation was done to make the situation more acceptable. (e) View showing the unfavorable angulation and incisocervical location of the implant that caused the prosthetic complications in (a). (Courtesy of Dr V. Meserkhani.)

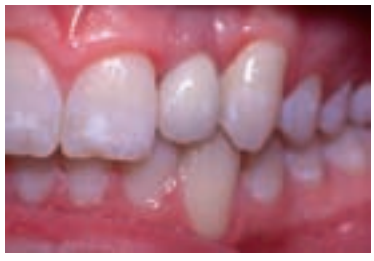


Fig. 10.25 Facial view of the cemented crown. While the soft-tissue contours are acceptable, it would be more ideal if the mesial interdental papilla extended farther incisally.

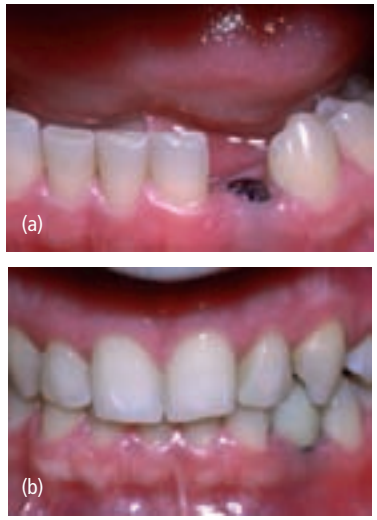


Fig. 10.26 (a) The final soft-tissue result present around a mandibular implant in the canine area. (b) Following crown cementation on an abutment, there was some soft-tissue recession that exposed metal. Fortunately, the area was not visible and was not problematic.

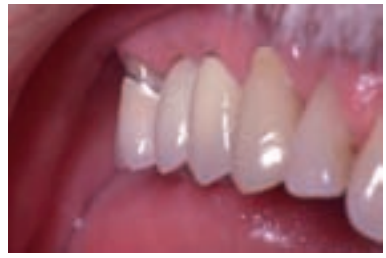


Fig. 10.27 The completed metal ceramic crown has been cemented over the abutment. The cervical contour is slightly deficient compared to adjacent teeth.

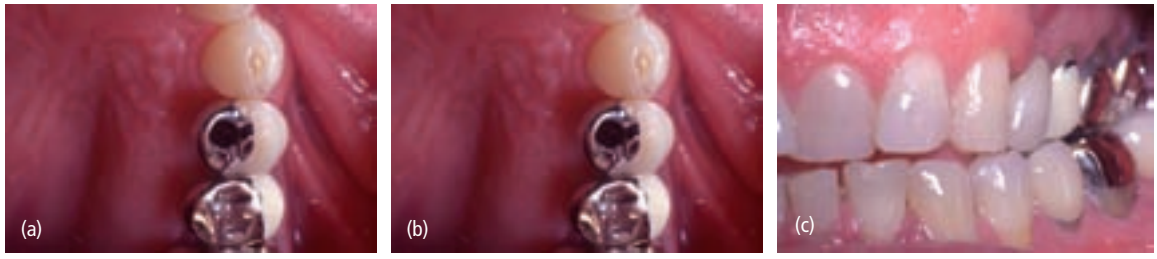


Fig. 10.28 (a) Cast resulting from an implant-level impression. Note that the implant is positioned to the mesial and slightly to the lingual. (b) To improve the cervical contour, it was necessary to fabricate the crown so it overlaps the facial soft tissue. (c) The completed crown required considerable creative contouring and overlapping of the soft tissue to achieve an appropriate esthetic result.

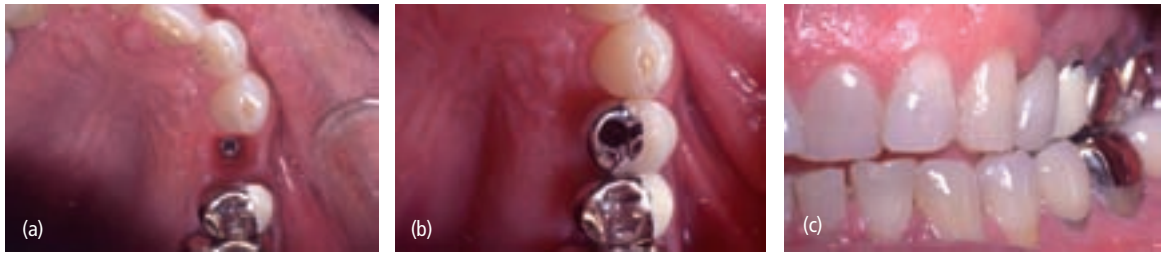


Fig. 10.29 (a) The maxillary first premolar implant was positioned lingual to the center of the adjacent teeth. (b) Occlusal view of the crown showing the occlusal screw access hole located toward the lingual aspect of the crown. (c) Facial view of the completed crown with a substantial amount of ceramic material overlapping the soft tissue.

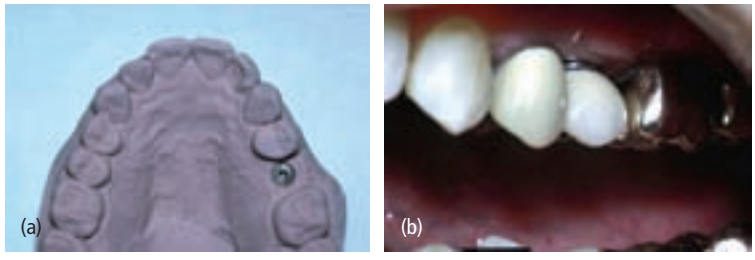


Fig. 10.30 (a) An implant placed lingual to the center of the adjacent teeth. (b) The second premolar crown was fabricated without any overlapping of the facial soft tissue, producing a strange form.

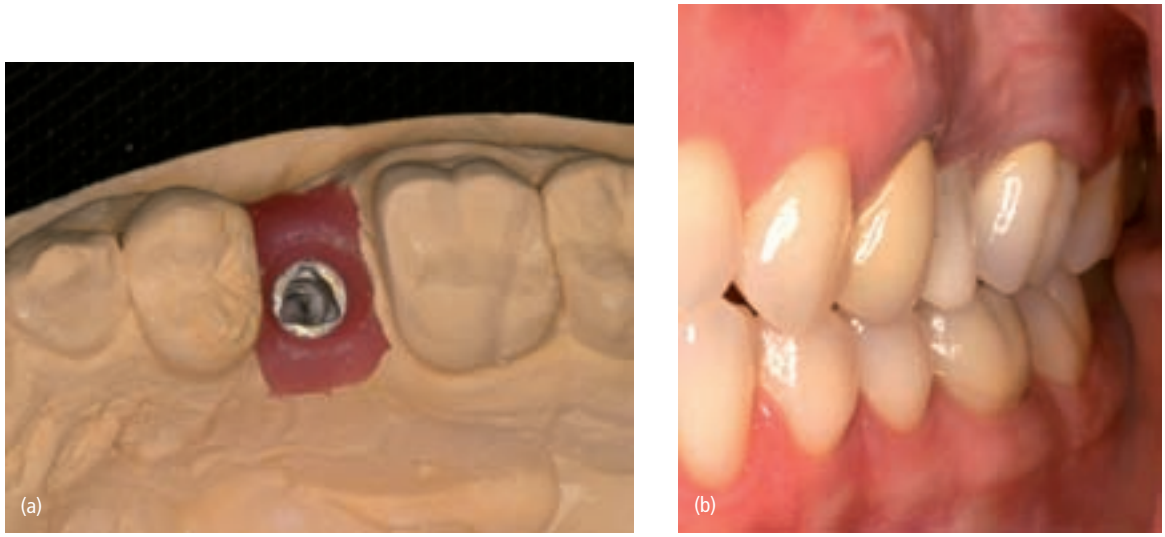


Fig. 10.31 (a) Cast showing lingual location of implant. (b) Provisional restoration showing the poor emergence form for the implant situation shown in Fig. 10.30(a).

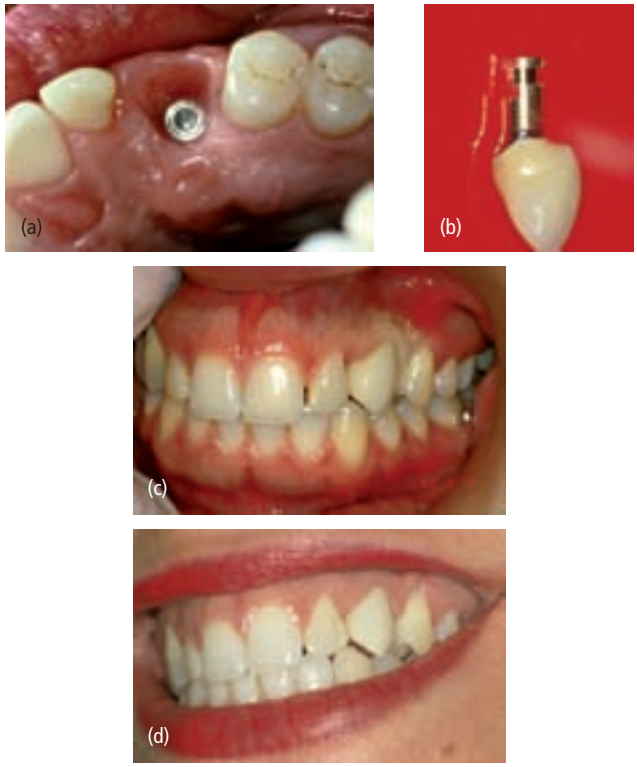


Fig. 10.32 (a) A lingually positioned implant where an ovate crown form will be used. (b) View of the ovate crown attached to an implant analog. (c) The crown after placement onto the implant. Note the initial blanching of the soft tissue. (d) A postplacement view of the ovate crown. (Courtesy of Dr R. Yanase.)

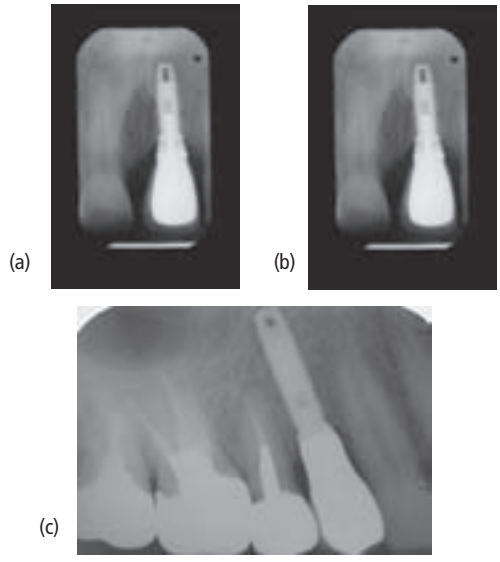


Fig. 10.33 (a) Periapical radiograph made after cementation of metal ceramic crown. (b) Periapical radiograph of an implant that was placed about 3 mm apical to the cementoenamel junction of adjacent teeth. The distance from the incisal edge to the top of the implant can become fairly substantial, permitting greater forces to be applied to the metal components. (c) An implant was placed into a severely resorbed maxillary first premolar site. The distance from the implant to the occlusal surface is almost equal to the length of the implant.

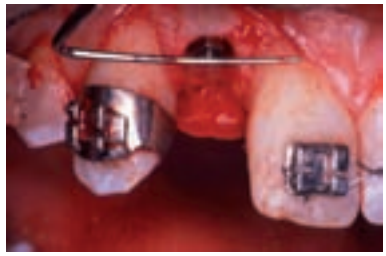


Fig. 10.34 A periodontal probe has been placed at a level that corresponds to the cementoenamel junctions of the adjacent teeth. The implant has been placed apical to the line represented by the probe. (Courtesy of Dr O. Hanisch.)

placed into the anterior maxilla of 26 patients. Fifty-two papillae were evaluated to determine the effect of the proximal bone crest on the presence or absence of papillae between an implant and an adjacent tooth. A papilla was present 100% of the time when the distance from the proximal contact point between the implant crown and the adjacent natural tooth to the interproximal bone crest was 5 mm or less. The papilla was only present 50% of the time when the distance from the contact point to the bone was equal to or greater than 6 mm.

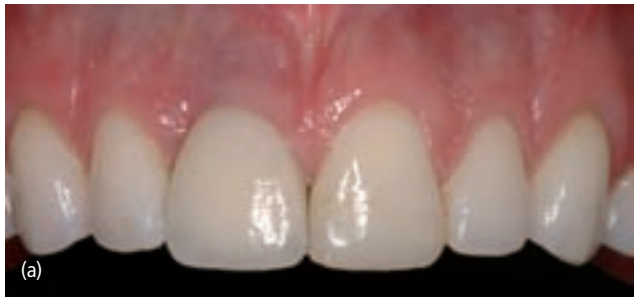
Measurements have been made of the dimension of the peri-implant mucosa (distance from the soft-tissue crest to the underlying bone crest) adjacent to implants and also the interproximal dentogingival complex dimension (distance from the gingival margin to the bone) on the teeth adjacent to these implants (26). The effect of the periodontal biotype (thick versus thin soft tissue) on the peri-implant mucosa dimension has also been assessed. This information is helpful in determining the likelihood of retaining interdental papillae between single implants and natural teeth. The dimensions of the peri-implant mucosa around 45 maxillary anterior single-implant crowns were measured by bone sounding using a periodontal probe. The dimensions were obtained at the mesial, distal, and midfacial aspects of each implant and the proximal aspects of the natural teeth on each side of the implant. Bone sounding measurements between 5 and 7 mm comprised 71% of the mesial peri-implant dimensions and 75% of the distal peri-implant dimensions. The midfacial peri-implant mucosa dimension was between 3 and 4 mm, 71% of the time. The interproximal bone sounding measurements on the teeth located mesial to the implants ranged from 3 to 4 mm on 32 of the 45 teeth. The measurements were between 3 and 4 mm on 31 of 45 natural teeth distal to the implants. The individuals with thick gingival had bone sounding measurements that were significantly greater than the patients with thin gingiva. As a result of these data, the authors suggest that papillae adjacent to implants "can seldom be recreated beyond 4 mm" when treating patients with thin gingiva (26).

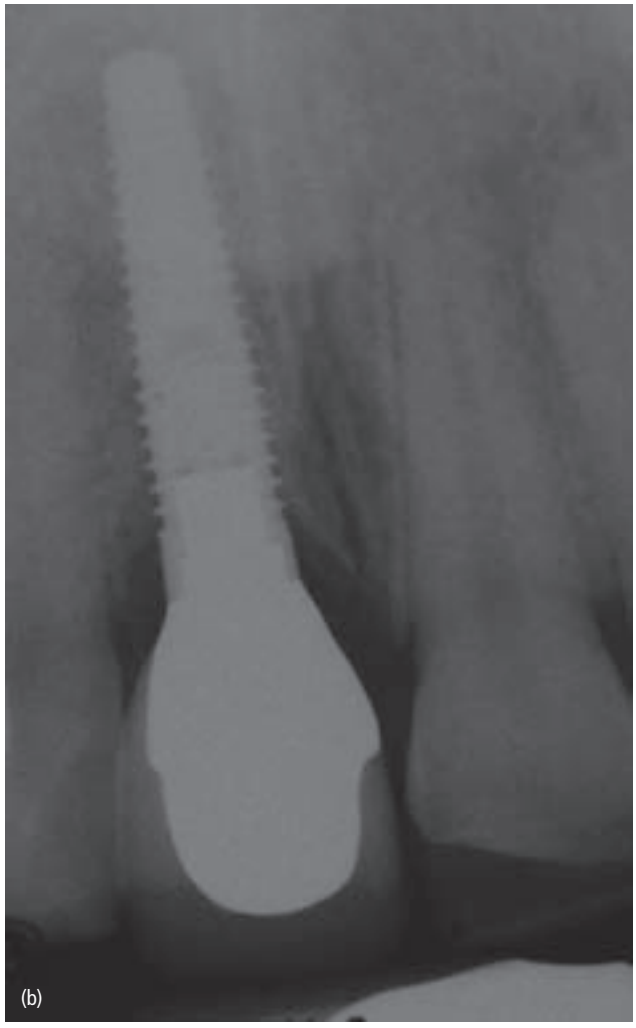
The distance between adjacent implants can also affect the presence of an interdental papilla (27). Radiographic measurements of crestal bone loss were made in 36 patients who had two adjacent implants. The radiographs were made 1–3 years after second stage surgery using a customized XCP radiographic bite block. The average crestal bone loss between implants with more than 3 mm of separation was 0.45 mm ($n = 11$). When the implants were separated by 3 mm or less, the average crestal bone loss was 1.04 mm ($n = 25$). This study proposes that 3 mm or more of bone should be retained between adjacent implants to minimize crestal bone loss, particularly in esthetic zones. The authors indicate that the crestal bone loss could determine whether an interdental papilla will be retained between the implants (27).

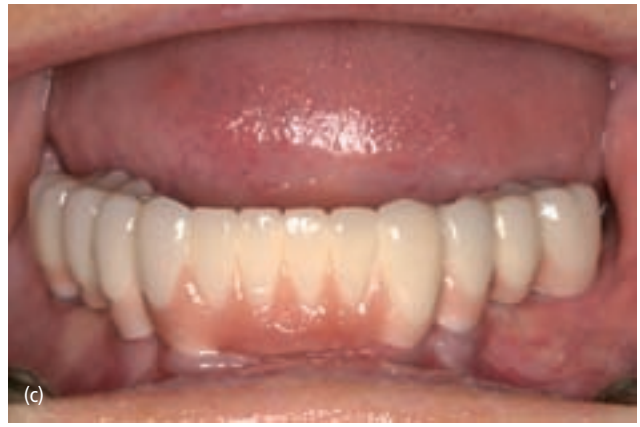
One study of 21 patients compared the use of a conventional surgical flap that included the interdental papilla with a design that did not sever the two interdental papillae when a single implant had been placed (28). The modified flap design preserved at least 1 mm of both papillae (adjacent to the natural teeth). A reduction in the crestal bone loss was noted which presumably would enhance the esthetic result achieved.

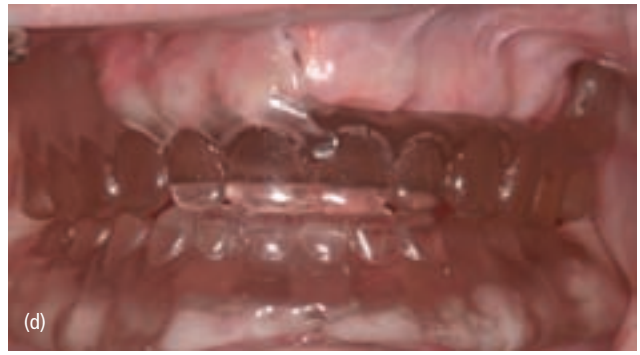
The longer the area has been edentulous, the more likely there will be a soft-tissue discrepancy due to bone resorption and concomitant changes in the soft-tissue contour. When there is a substantial esthetic deficiency as noted clinically or from a diagnostic wax pattern formed on a cast, bone and/or soft-tissue grafting may be necessary (Fig. 10.2c–e). However, some esthetic deficiencies are not totally correctable through grafting procedures and therefore it is generally felt that emphasis should be placed on retaining soft-tissue form rather than restoring lost tissue. Methods of retaining soft-tissue form and location include immediate implant placement and immediate placement of a provisional restoration when these procedures are indicated.

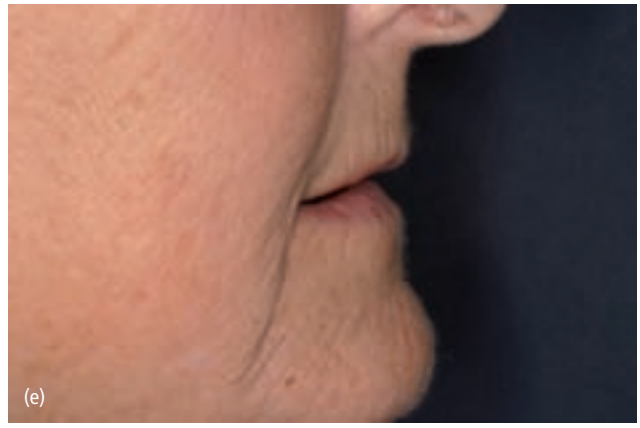
Immediate implant placement and provisionalization following extraction of a tooth has shown successful results in the maxillary esthetic zone, and papillae have been preserved (26). It has been judged to be most predictable when the prospective implant site possesses certain characteristics before tooth extraction. The dentogingival complex dimensions (distance from free gingival crest to the osseous crest) should ideally be 3 mm on the facial surface of the tooth to be extracted and 4.5 mm on the interproximal surfaces of the adjacent teeth. Deviations from these dimensions will likely produce deficits in the soft-tissue esthetics (26). Measurements have been made of the dimension of the peri-implant mucosa (distance from the soft-tissue crest to the underlying bone crest) adjacent to implants and also the interproximal dentogingival complex dimension (distance from the gingival margin to the bone) on the teeth











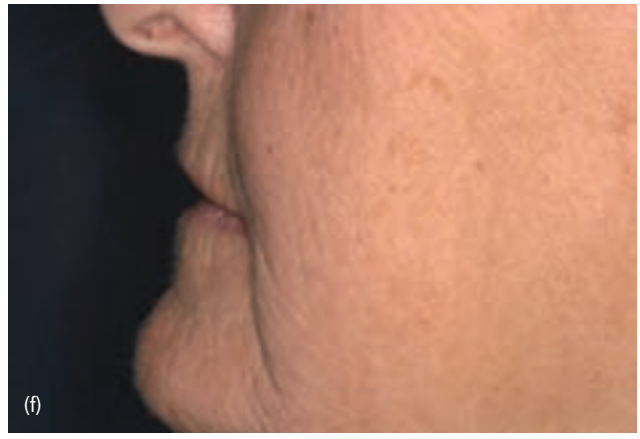


Fig. 10.35 (a) Interdental papillae around maxillary central incisor have filled in, to form acceptable soft-tissue contours. (b) Radiograph of implant crown seen in (a) showing optimal location of proximal bone in relation to restoration and implant. (c) Mandibular implant-supported fixed partial denture using gingiva-colored ceramic to improve cervical appearance. (d) Frontal view of duplicated maxillary complete denture with one side of the labial flange completely removed to simulate a maxillary fixed complete denture profile. (e) Lip support as seen from the right side. (f) Lip support as seen from the left side. This side reveals less support than the other side.

adjacent to these implants. The effect of the periodontal biotype (thick versus thin soft tissue) on the peri-implant mucosa dimension has also been assessed. This information is helpful in determining the likelihood of retaining interdental papillae between single implants and natural teeth.

A technique has been reported (29) whereby the papilla can be retained between adjacent single implants. This interimplant papilla preservation involves alternate immediate implant placement and provisionalization, one following the bone integration period of the other. The process involves extracting one of the two teeth, immediately placing the implant, attaching a provisional metal abutment with resin added to create the proper emergence profile, and a provisionalization with a resin crown. In this way, the soft tissue around the implant is preserved in its normal location. After 6 months, the procedure is repeated for the adjacent tooth, thereby preserving the interimplant papilla. The authors reported highly satisfactory esthetic results when treating six consecutive patients in this manner.

Depending on the interocclusal distance and the esthetic demands of the patient's residual tissue anatomy, reproduction of the natural root form without the gingival papilla can be accomplished. Gingiva-colored ceramic restorations can also be used to enhance the cervical appearance (Fig. 10.35c).

Consideration of emergence profile and transitional contours between the implant and definitive crown or prosthesis can be used to create natural profiles as they emerge from the gingival sulcus. Angled, custom abutments and the concept of increasing the transitional angles subgingivally when tissue height is minimal allow for the transition of the restoration from the round diameter of the implant to the form of a natural tooth as the restoration emerges from the gingival sulcus. Despite these efforts surgical correction may also be required to achieve the desired results (Fig. 10.24b–e).

Before treatment planning for a fixed complete denture in the maxillary arch, it is prudent to consider whether the prosthesis offers adequate lip support to the patient. It is advisable to duplicate, in resin, the patient's denture or an ideal teeth arrangement in wax with one side of the flange cut off to mimic the appearance of a fixed complete denture on one side and a conventional removable overdenture on the contralateral side. It can then be determined whether the lip is supported adequately by the flangeless side (mimicking a fixed complete denture) before making a decision regarding the type of prosthesis proposed to the patient (Fig. 10.35d–f). This also allows the patient to make an informed decision on the final prosthesis after viewing the support of the lips on the right and left sides of the face. Sometimes a maxillary fixed complete denture can create an esthetic complication by showing a discernible line on the lip when the patient smiles, revealing the extent of the prosthesis intraorally.

Biologic complications attributable to the prosthesis

Gingival inflammation and proliferation

Etiology

Gingival inflammation and proliferation around dental implants has been noted when implant overdenture bars (Fig. 10.36) or the frameworks associated with implant fixed complete dentures are placed too close to the tissue. It has also been noted with all types of prostheses when the oral hygiene is inadequate. In addition, loose and/or fractured screws allow excessive bacterial accumulation to occur that can produce this type of gingival response (Fig. 10.37a–e). It has been reported (30) that soft-tissue complications were more frequently encountered in the maxilla and this may be related to the reduced vertical space available in the maxilla. Gingival inflammation and proliferation has been more commonly observed with implant overdentures (19% of patients) and implant fixed complete dentures (11% of patients) than with other implant prostheses.

Prevention and treatment

Bars for implant overdentures and the cantilever extensions of fixed complete dentures should be located 1–2 mm above the soft tissue (Fig. 10.38). The patient must be shown how to clean adequately around their prostheses and they must be encouraged to maintain a high level of homecare. It has been stated that good oral hygiene is the main factor in preventing adverse soft-tissue responses (31).

A loose or fractured abutment screw can produce localized gingival inflammation and proliferation. If a screw has come loose or has fractured, it should be tightened or replaced and that usually eliminates the soft-tissue complication (Fig. 10.37a, b).

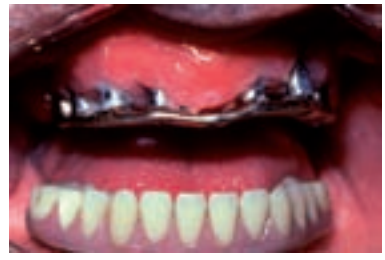


Fig. 10.36 The gingival tissues have proliferated around the implants and bar under a maxillary implant overdenture. Note the less than ideal oral hygiene present.

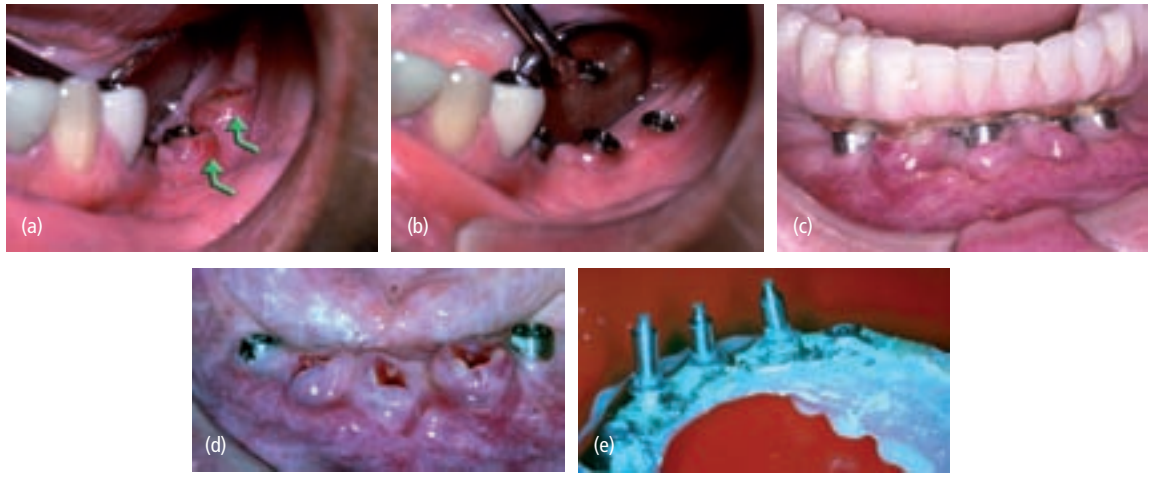


Fig. 10.37 (a) Note the irregular, unhealthy tissue that proliferated around these implants where loose abutment screws were present. (b) Retightening the abutment screws created a significant improvement in the soft tissues in 2 weeks and the tissue subsequently returned to normal appearance with no radiographically discernible changes. (c) Multiple abutment screws have fractured and the resulting gaps between the parts allowed bacterial accumulation to occur, resulting in gingival hyperplasia. (d) The prosthesis has been removed, revealing the condition of the soft tissue. (e) The undersurface of the prosthesis showing the abutments with fractured screws attached to the prosthesis. (c–e: Courtesy of Dr R. Yanase.)

Extensive soft-tissue proliferation as a result of long-standing poor hygiene may require soft-tissue surgery to remove the proliferative, unhealthy tissue. One paper reported that 11 of 25 patients had peri-implant inflammation/hyperplasia and two of these patients required surgery (32).

Fistulae

Etiology

Fistulae have been noted when there are loose and/or fractured screws that attach a crown, prosthesis, or prosthetic component to an implant (Fig. 10.39). The fistula is commonly located at the level where the mechanical deficiency is located. Fistulae have also been noted around cemented crowns and prostheses when there is excess cement retained subgingivally (Fig. 10.40a, b) (33). The problem is exacerbated by deep subgingival margins that make it difficult to remove excess cement (33).

In situations where two-stage surgery is used, insufficient tightening of the implant cover screw may result in its loosening and the development of a fistula within a few days of surgery.

Prevention and treatment

Loose and/or fractured screws should be tightened or replaced and this will resolve the fistula. When implant crowns or prostheses are cemented, the excess cement should be carefully removed and the sulcus inspected for any remnants of cement left behind. It is wise not to place the crown or prosthesis margins too deep into the sulcus as it becomes difficult to determine whether excess cement is present. Some fistulae related to excess cement require surgical flap reflection to remove the excess cement.

Multiple patient treatments have been reported that illustrate complications associated with the cementation of crowns on implants. Patient 1 presented with purulent swelling of the facial peri-implant tissue, and when a flap was reflected there was excess cement present. Patient 2 presented with acute swelling of the peri-implant tissues, a 9 mm probing depth, and radiographic

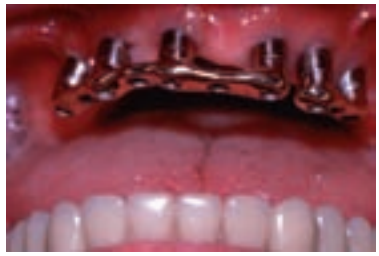


Fig. 10.38 There is sufficient space between the underside of the bar and the soft tissue for effective oral hygiene procedures to be performed.

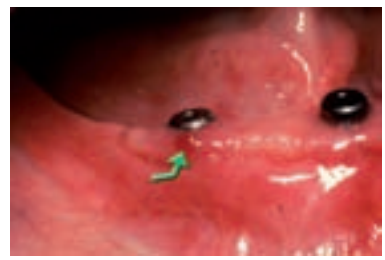


Fig. 10.39 Fistula located facial to the mandibular right implant.

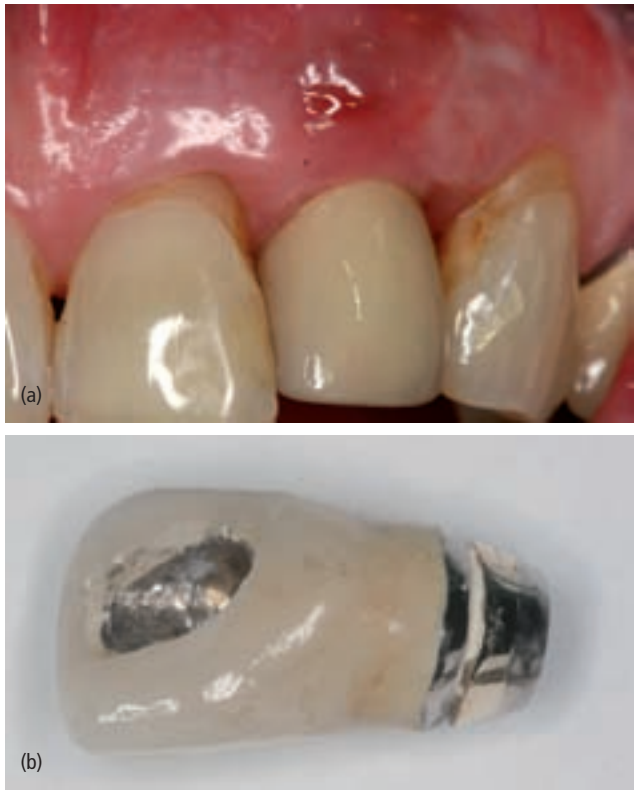


Fig. 10.40 (a) A fistula developed around the central incisor crown that was cemented over an implant abutment. (b) Crown removal was required to remove the excess resin cement that was located subgingivally.

bone loss a few weeks after an implant single crown was cemented. A flap procedure revealed excess cement. Patient 3 exhibited facial peri-implant tissue swelling 5 months after cementation of a crown, a 6–7 mm probing depth, and some radiographic bone loss. Excess cement was again found after reflection of a flap. Patient 4 had peri-implant swelling, soreness, increased probing depths, bleeding and/or exudates when probing, and radiographic bone loss 3 years after recementation of an implant single crown. Excess cement was removed during a flap reflection and the tissue healed (33).

A cement should be selected where the marginal excess is easy to remove. A provisional cement is recommended where there is sufficient retention provided by the abutment. When a definitive cement is needed because of a short abutment, zinc phosphate is recommended as opposed to glass-ionomer or resin cements. It has been shown that zinc phosphate cement is easier to remove and resin cements are the hardest to remove (34).

Techniques to minimize excess cement have been proposed when cementing crowns on implants (35). One recommendation is to place luting agent only in the occlusal half of the crown (35). Another suggestion, when using an unmodified prefabricated abutment, is to cement the crown on an abutment analog on the bench, quickly unseat the crown, and then cement it over the abutment in the mouth (35).

Postplacement appointments are important following cementation and it has been suggested that patients be scheduled no later than 1 week after cementation and regularly after that (1 month, 3 months, and 6 months) (33).

Swallowing an instrument or implant component

Etiology

An instrument such as a screwdriver or any of the implant components can be dropped while placing them into the mouth and removing them from the mouth. They can be inadvertently swallowed when they land in the back of the mouth.

Prevention and treatment

Good surgical technique, including the use of a throat pack when small instruments, screws, abutments, or implants are inserted in the oral cavity, is the best way to avoid inadvertent swallowing or aspiration. Using floss in directional or indicator instruments can make retrieval of these easy if they shift position, or go under or over the tongue. Floss should always be tied to screwdrivers to permit retrieval should they inadvertently slip out of the fingers (Fig. 10.41). Throat packs or pharyngeal screens are also effective for intubated patients.

If an instrument or other foreign body such as an implant component is inadvertently swallowed, a chest radiograph should immediately be made and evaluated (Fig. 10.42a, b). A specialist should be consulted to determine whether the foreign body should be removed or whether it is likely to pass through the gastrointestinal tract.

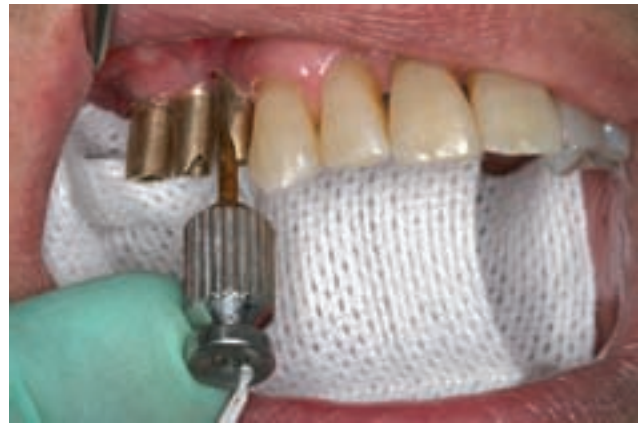


Fig. 10.41 View showing a screwdriver being used with dental floss attached to it. Note also the throat pack, which will prevent accidental aspiration of implant components

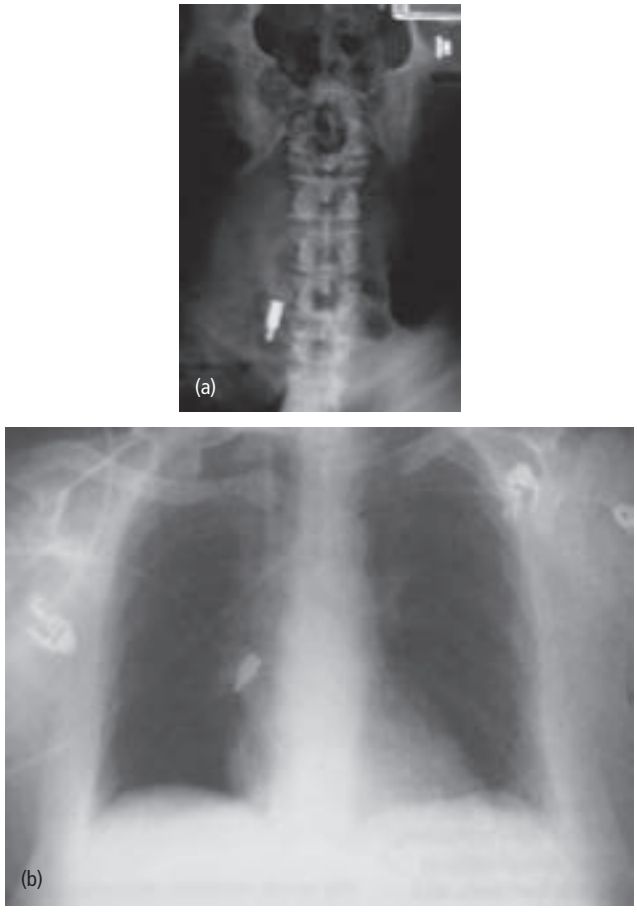


Fig. 10.42 (a, b) Radiographs showing a screwdriver that was swallowed.

Conclusions

The general causes of intraoperative, postoperative, and postprosthetic complications have been outlined, examples presented of the major causes of these complications, and proposals made and examples given regarding the prevention and management of the complications that have been encountered when placing and restoring endosseous root form implants. While this management information is important and highly relevant today, recent advances suggest that the incidence of complications associated with all types of implant prostheses would likely be much lower if the studies that produced the data were repeated with today's knowledge, skill, and technology. In fact, certain complications might not even occur at a level that would warrant their inclusion in a discussion of complications and their management.

The causes of prosthetic complications are related to many factors, but principal among them are inadequate treatment planning, less than optimal prosthesis design and/or fit, characteristics of the patient, failure to use a surgical template, and failure to follow specified protocols.

Diagnosis must include identification of patient factors such as the amount and location of available bone, occlusal forces, habits present, the level of oral hygiene, and the motivation to participate in a regular program of professional examinations and cleanings. When implants will be placed to support and retain single crowns, it is important to determine the periodontal biotype and the distance between the interproximal bone crest, and the location where the proximal contact will be present between the implant crown and natural tooth. This distance helps to determine whether the interdental papilla will fit the cervical embrasure space.

It is important to minimize cantilevers on implant single crowns, fixed partial dentures, and fixed complete dentures. With single crowns and fixed partial dentures, every effort should be made to center the implants beneath the occlusal surfaces. With fixed complete dentures, the implants should be placed in a symmetric, curved relationship around the arch and there should be at least 10 mm of anterior posterior dimension to the arch curvature. Posterior cantilevers should not exceed twice the anteroposterior dimension in the mandible and should not exceed the anteroposterior dimension in the maxilla.

Implant overdentures should be designed so that any bars are located 1–2 mm above the mucosa to facilitate oral hygiene and prevent gingival inflammation and proliferation. The same relationship also applies to implant fixed complete dentures.

When single crowns are cemented on implants, removal of excess cement is crucial to maintain soft-tissue health. Provisional or zinc phosphate cements are recommended, as opposed to glass-ionomer and resin cements, which are nearly impossible to remove completely.

To avoid swallowing or aspiration of implant components or screwdrivers, a throat pack should be present and floss should be tied to screwdrivers.

The management of complications reported in the literature encompasses a range of interventions from simple adjustment to completely new restorations and prostheses. The most prevalent complications are associated with removable prostheses, which need more frequent adjustments than other prostheses and by their nature are more subject to wear of their retentive components. Many of the complications such as implant fracture, screw fracture, and material fractures have been addressed through new materials and implant designs. A more in-depth understanding and knowledge related to fit, preload, and materials has also helped alleviate previous complications.

Implant overdentures have more complications than any other type of implant prosthesis. Despite the higher incidence of complications associated with implant overdentures, there is evidence to support their use as a

primary treatment option for completely edentulous patients. However, such a decision comes with the clinical expectation that more time and expense will be required for adjustments and repairs. The inclusion of such information should be an integral part of any published guidelines related to the use of overdentures as the treatment of first choice for completely edentulous patients. It is also important that the patient is informed of the potential risks, benefits, and alternatives to the proposed treatment. If the patient is aware of the potential complications of proposed therapy, they might be more accepting of complications and the fees incurred for managing them.

While the chapter is dedicated to addressing the management of prosthodontic complications in implant dentistry, it is also important to recognize that skilled diagnosis and treatment planning should remain the foundation on which all prosthodontic treatment decisions and prosthesis designs are based. Torabinejad *et al.* (36) published a systematic review of outcomes of root canal treatment and restoration, implant-supported single crowns, fixed partial dentures, and extraction without replacement. Both implants and root canal treatments resulted in superior long-term survival, compared with fixed partial dentures. Survival of teeth with initial root canal treatment and survival of single implants were comparable in this report. An in-depth knowledge of evidence-based science plays an important role in the treatment planning process. By using sound prosthodontic principles and judgment, the focus of the clinician should be to save the remaining teeth if possible. As DeVan phrased more than half a century ago, "Our objective should be the perpetual preservation of what remains rather than the meticulous restoration of that which is missing" (37).

With dental implants, for the first time, we have also established a relationship that involves a manufacturing company where components are usually specific to a particular implant system. Will parts always be available? Goodacre *et al.* reported on different mechanical complications related to dental implant prostheses (1). To address most mechanical complications one would require access to implant components. Jokstad *et al.* (38) identified more than 220 implant brands produced by about 80 different manufacturers. They further report that the implants are made from different materials, undergo different surface treatments, and come in different shapes, lengths, widths, and forms. Although the thrust of this article was to comment on the quality of dental implants, one cannot ignore the fact that there is a real possibility that different implant systems will not be readily available in the future for changing or replacing prosthetic components. With the increasing success and longevity of dental implants, this is a prosthodontic complication that may confront us in the future.

The rich heritage of implant dentistry, as realized through multiple dental specialties, has produced substantial advancements that have enhanced dental implant treatment and improved the lives of countless numbers of patients throughout the world. Recent history predicts continued substantial improvements in the biologic, esthetic, functional, and technical aspects of dental implant therapy. While nothing can replace our natural oral function, it has been possible to approximate the ideal more closely through implant dentistry than with any previous treatment modality. The authors look forward with anticipation to the possibilities that will become reality as we continue our commitment to excellence in education, research, and patient care. We hope that one day there will no longer be a need for chapters related to implant prosthodontic complications and their management.

Take-home hints

- Take time during diagnosis and treatment planning to review thoroughly every detail and aspect of the presenting patient situation.
- Precise surgical placement can only be assured by providing a surgical template. A properly placed implant is a major contributor to long-term success and avoidance of prosthetic complications.
- When planning implant prostheses, take a moment to think about potential prosthetic complications and how you would address them if they were to happen.
- In every situation, ensure that risks, benefits, and alternatives to the proposed treatment are clearly outlined to the patient in writing and consent is obtained before treatment begins. While this will not prevent prosthetic complications, it will help the patient to have realistic expectations regarding the definitive treatment.

References

1. Goodacre CJ, Kan JYK, Rungcharassaeng K. Clinical complications of osseointegrated implants. *J Prosthet Dent* 1999; **81**: 537–52.
2. Albrektsson T, Zarb G, Worthington P, Eriksson AR. The long-term efficacy of currently used dental implants: a review and proposed criteria for success. *Int J Oral Maxillofac Implants* 1986; **1**: 11–25.
3. Garg LC. Preventing and treating infections related to dental implant placement. *Dent Implantol Update* 2001; **10**: 73–7.
4. Tarnow DP, Cho SC, Wallace SS. The effect of inter-implant distance on the height of inter-implant bone crest. *J Periodontol* 2000; **71**: 546–9.

5. Waskewicz GA, Ostrowski JS, Parks VJ. Photoelastic analysis of stress distribution transmitted from a fixed prosthesis attached to osseointegrated implants. *Int J Oral Maxillofac Implants* 1994; **9**: 405–11.
6. Adell R, Lekholm U, Rockler B, Brånemark P-I. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. *Int J Oral Surg* 1981; **10**: 387–416.
7. Esposito M, Hirsch J-M, Lekholm U, Thomsen P. Biological factors contributing to failures of osseointegrated oral implants. (II) Etiopathogenesis. *Eur J Oral Sci* 1998; **106**: 721–64.
8. Esposito M, Hirsch J, Lekholm U, Thomsen P. Differential diagnosis and treatment strategies for biologic complications and failing oral implants: a review of the literature. *Int J Oral Maxillofac Implants* 1999; **14**: 473–90.
9. Boyne PJ, Herford AS. An algorithm for reconstruction of alveolar defects before implant placement. In: Boyne PJ, guest ed. *Oral and Maxillofacial Surgery Clinics of North America. Alveolar ridge reconstruction/guided tissue regeneration and bone grafting*. Philadelphia, PA: WB Saunders, 2001; **13**(3): 533–41.
10. Lazzara RJ. Esthetic and restorative benefits of non-axially loaded implants [abstract]. *Implant Dent* 1995; **4**: 282–3.
11. Jacobs R, Schotte A, van Steenberghe D, Quirynen M. Posterior jaw bone resorption in osseointegrated implant-supported overdentures. *Clin Oral Implants Res* 1992; **3**: 63–70.
12. Haraldson T, Carlsson GE. Bite force and oral function in patients with osseointegrated oral implants. *Scand J Dent Res* 1977; **85**: 200–8.
13. Carr AB, Laney WR. Maximum occlusal force levels in patients with osseointegrated oral implant prostheses and patients with complete dentures. *Int J Oral Maxillofac Surg* 1987; **2**: 101–8.
14. Fontijn-Tekamp FA, Slagter AP, van der Bilt A, van't Hof MA, Witter DJ, Kalk W, Jansen JA. Biting and chewing in overdentures, full dentures, and natural dentitions. *J Dent Res* 2000; **79**: 1519–24.
15. Sadowsky SJ. Mandibular implant-retained overdentures: a literature review. *J Prosthet Dent* 2001; **86**: 468–73.
16. Al-Turki LEE, Chai J, Lautenschlager EP, Hutten MC. Changes in prosthetic screw stability because of misfit of implant-supported prostheses. *Int J Prosthodont* 2002; **15**: 38–42.
17. Clausen GF. The lingual locking screw for implant-retained restorations – aesthetics and retrievability. *Aust Prosthodont J* 1995; **9**: 17–20.
18. Chee WWL, Torbati A, Albouy JP. Retrievable cemented implant restorations. *J Prosthodont* 1998; **7**: 120–5.
19. Okamoto M, Minagi S. Technique for removing a cemented superstructure from an implant abutment. *J Prosthet Dent* 2002; **87**: 241–2.
20. Doerr J. Simplified technique for retrieving cemented implant restorations. *J Prosthet Dent* 2002; **88**: 352–3.
21. Williamson RT, Robinson FG. Retrieval technique for fractured implant screws. *J Prosthet Dent* 2001; **86**: 549–50.
22. Rangert B, Jemt T, Jörneus L. Forces and moments on Brånemark implants. *Int J Oral Maxillofac Implants* 1989; **4**: 241–7.
23. Balshi TJ. Preventing and resolving complications with osseointegrated implants. *Dent Clin North Am* 1989; **33**: 821–68.
24. Small PN, Tarnow DP. Gingival recession around implants: a 1-year longitudinal prospective study. *Int J Oral Maxillofac Implants* 2000; **15**: 527–32.
25. Choquet V, Hermans M, Adriaenssens P, Daelemans P, Tarnow DP, Malevez C. Clinical and radiographic evaluation of the papilla level adjacent to single-tooth dental implants. A retrospective study in the maxillary anterior region. *J Periodontol* 2001; **72**: 1364–71.
26. Kan JYK, Rungcharassaeng K, Umezu K, Kois JC. Dimension of peri-implant mucosa: an evaluation of maxillary anterior single implants in humans. *J Periodontol* 2003; **74**: 557–62.
27. Tarnow DP, Cho SC, Wallace SS. The effect of inter-implant distance on the height of inter-implant bone crest. *J Periodontol* 2000; **71**: 546–9.
28. Gomez-Roman G. Influence of flap design on peri-implant interproximal crestal bone loss around single-tooth implants. *Int J Oral Maxillofac Implants* 2001; **16**: 61–7.
29. Kan JYK, Rungcharassaeng K. Interimplant papilla preservation in the esthetic zone: A report of six consecutive cases. *Int J Periodont Restor Dent* 2003; **23**: 249–59.
30. Jemt T, Book K, Lindén B, Urde G. Failures and complications in 92 consecutively inserted overdentures supported by Brånemark implants in severely resorbed edentulous maxillae: a study from prosthetic treatment to first annual check-up. *Int J Oral Maxillofac Implants* 1992; **7**: 162–7.
31. Naert I, De Clercq M, Theuniers G, Schepers E. Overdentures supported by osseointegrated fixtures for the edentulous mandible: a 2.5-year report. *Int J Oral Maxillofac Implants* 1988; **3**: 191–6.
32. Hemmings KW, Schmitt A, Zarb GA. Complications and maintenance requirements for fixed prostheses and overdentures in the edentulous mandible: a 5-year report. *Int J Oral Maxillofac Implants* 1994; **9**: 191–6.
33. Pauletto N, Lahiffe BJ, Walton JN. Complications associated with excess cement around crowns on osseointegrated implants: a clinical report. I*nt J Oral Maxillofac Implants* 1999; **14**: 865–8.
34. Agar JR, Cameron SM, Hughbanks JC, Parker MH. Cement removal from restorations luted to titanium abutments with simulated subgingival margins. *J Prosthet Dent* 1997; **78**: 43–7.
35. Dumbrique HB, Abanomi AA, Cheng LL. Techniques to minimize excess luting agent in cement-retained implant restorations. *J Prosthet Dent* 2002; **87**: 112–14.
36. Torabinejad M, Anderson P, Bader J, Brown LJ, Chen LH, Goodacre CJ, *et al.* Outcomes of root canal treatment and restoration, implant-supported single crowns, fixed partial dentures, and extraction without replacement: a systematic review. *J Prosthet Dent* 2007; **98**: 285–311.
37. DeVan MM. Biological demands of complete dentures. *J Am Dent Assoc* 1952; **45**: 524–7.
38. Jokstad A, Bragger U, Brunski JB, Carr AB, Naert I, Wennerberg A. Quality of dental implants. *Int Dent J* 2003; **53**(6 Suppl 2): 409–43.

Chapter 11

Complications associated with single-implant esthetics: prevalence, etiology, prevention, and treatment

Dario Adolfi DDS, CDT *and Oswaldo Scopin de Andrade* DDS, MS, PhD

Introduction

Significant advances in the areas of diagnosis and treatment planning have been made in the past few years, which have improved the predictability of implant therapy. Several research centers have demonstrated evidence of high survival and success rates for implant-supported restorations in fully and partially edentulous patients (1–3). Nevertheless, many clinicians obtain less than ideal clinical outcomes in terms of esthetics and function. Lack of knowledge and proper training may result in incorrect treatment planning that can lead to complications which compromise the chances of achieving successful final restorations. Most studies involving implants focus on how long the implants are in function, and the bone response around the fixtures. These factors are important, but are only part of the criteria for implant success in the "esthetic zone" of the anterior maxilla where esthetics is a major concern for both patients and clinicians. Often, in spite of the clinician's effort in the areas of function and esthetics, the final restoration does not fulfill the patient's expectations. This may be due in large part to a lack of congruency in patient expectations and what can be clinically achieved.

Osseointegration is a predictable and well-documented phenomenon. The efforts of the scientific community are now being directed towards the key factors that render predictable outcomes with good esthetics (4). Today, the clinician's major concern with regard to single implants in esthetic areas is to perform precise implant placement in a 3D manner. Adequate planning also requires an understanding of the problems that may occur if a customized treatment plan is not followed (5).

The main objective of this chapter is to understand why esthetic complications occur with single implants, and how to treat these problems. Guidelines to avoid these complications will also be discussed.

Prevalence of complications

There are several studies in the literature that document esthetic complications with single implants, compared with full-mouth implant-supported restorations (4–6).

In a paper by Belser *et al.* (4), numerous studies on the use of implant therapy in the esthetic zone were reviewed. It was concluded that the survival of implants in esthetic areas is similar to that reported for other segments of the jaws. However, the authors indicated that most of the studies reviewed did not include well-defined esthetic parameters.

Meijer *et al.* discussed the lack of a suitable index for rating the esthetics of implant restorations (7). They concluded that most of the indices available are borrowed from other types of treatment, and may not be useful for implants. Based on this, a unique index rating for restorations in the esthetic zone was introduced. Nine parameters were proposed, including the anatomic shape, color and contour of the crown, as well as the characteristic of the peri-implant soft tissue. The authors used slides to test the validation of the method and concluded that the Implant Crown Aesthetic Index is an objective tool for rating esthetics of oral implants (7). A pink esthetic score (PES) was proposed by Fürhauser *et al.* (8) to evaluate the soft tissue around single-implant restorations. This score was developed to determine the esthetic result in anterior crowns by analyzing seven points, and the authors found that is possible to reproduce the score. Gehrke *et al.* (9) tested the reproducibility of the PES, resulting in good agreement among the examiners, showing that this method may be an option to assess esthetic quality.

Another article evaluated the results of single-tooth implant therapy in patients who had lost teeth through trauma (10). The evaluation was performed by both patients and professionals. The degree of satisfaction was as high as 91%, with a 97% score for height and

shape of the crown. The most common prosthetic complication (12%) was crown loosening that required recementation with no further problems. After analyzing the results, it may be concluded that with correct treatment planning and execution a high level of professional and patient satisfaction can be achieved. Moreover, from a technical point of view, problems such as failures due to poor cementation can be easily remedied. This article demonstrated that when appropriate planning and treatment are performed, complications are relatively simple and easy to solve.

In summary, the keys to success were found to be proper diagnosis and case selection. However, other esthetic implant complications are not always simple or easily solved.

Etiology of complications related to single implants

There are many causes of esthetic complications with single-implant restorations, which include iatrogenic factors caused by inadequate treatment planning, surgical or prosthetic errors (10).

The clinician who places an implant must have knowledge of anatomy, gingival and bone healing responses to surgical insult, occlusion, and the restorative options for the implant type, design, and size. Implant dentistry in the esthetic zone presents many issues that must be addressed and analyzed to avoid complications in this area.

Insufficient understanding of the anterior maxillary anatomy may result in inadequate treatment planning. Incorrect analysis can lead to implant placement in available bone in areas with horizontal and/or vertical bone deficiencies, leading to implant malposition. Critical aspects discussed in this chapter will guide the clinician to understand both the etiology of implant complications and how to correct and prevent them, thus avoiding treatment failures. When dealing with single implants in the esthetic zone the possible complications include the following.

Deficiency of papillae

The presence of the papillae in natural dentition is dependent on several factors, including bone height, dimension of the interproximal space, and the distance from the alveolar crest to the contact point of the restoration (11). Tarnow *et al.* (12) found that a maximum distance of 5 mm, with an average of 4.2 mm, from the interproximal alveolar crest to the contact point, will almost always result in intact papillae. In natural dentition, patients with advanced periodontal disease, or a history of trauma, root resorption, or iatrogenic restorative procedures may have a deficiency of intraproximal soft tissue. In those situations in which extraction of the natural tooth would result in a deficient papilla, orthodontic forced eruption is a useful tool to coronally advance bone and soft tissue before tooth extraction (13, 14). Orthodontic extrusion and periodontally oriented orthodontics, described by Salama and Salama (13), can vertically increase the osseous dimension and preserve papillae. This technique brings the tissue and bone into a position that may enable the implant to be placed in a more ideal position. To protect and maintain the bone and soft-tissue architecture, atraumatic tooth extraction is critical to the success of the treatment. It is helpful to use small instruments and periotomes to minimize damage to the surrounding bone and soft tissue during tooth extraction. Atraumatic tooth extraction is necessary for delayed as well as for immediate implant placement. In cases of delayed implant placement, socket preservation techniques have been proposed which minimize marginal bone resorption (15–17).

In implant therapy the presence of papilla and the level of bone is the primary factor determining soft-tissue contour, which is followed by volume of connective tissue and proximal contact (18). For a single-tooth implant the presence of the papilla is determined by the bone and periodontal attachment on the natural tooth side, which must not be less the 1.5 mm on each side (18).

For an intact papilla to be present, bone must be present on the teeth adjacent to the implant to support soft tissue (19). Even with the large number of papers that provide guidance for predictable implant treatment planning (20–24), there is often a failure to evaluate the site before implant placement. Papilla deficiency (Fig. 11.1) is one of the most common failures seen around single restored implants. This problem is especially difficult to correct when the implant has integrated. A deficient papilla is not only an esthetic complication, but can also result in food impaction and speech problems. The presence or absence of the papillae around implants can be

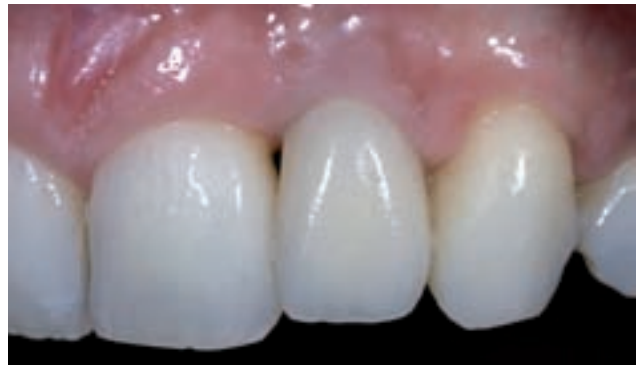


Fig. 11.1 An example of missing papilla between teeth 9 and 10.

anticipated even before the extraction of a hopeless tooth by measuring the distance from the proximal bone to contact point. This can be done by transmucosal probing through the sulcus, under local anesthesia and/or by radiographic means. When the distance is less than 5 mm (4.2 mm), the chances of having complete papillae around the implant restoration is excellent. In those cases when a papilla deficiency is anticipated because the distance is greater than about 5 mm, a thorough discussion with the patient is recommended, advising that prosthetic adjustments will be necessary (i.e. long contact point), before initiation of treatment.

Poor gingival emergence profile

Another problem experienced by clinicians is the inadequate emergence profile of the implant-supported restoration. An understanding of the consequences of tooth loss is necessary to understand the etiology of this problem. In a recent article, Coachman *et al.* (25) explained that an incorrect emergence profile often results in prosthetic deficiencies that are impossible to correct by the dental technician and the restorative dentist without artificial composite or pink ceramic. After tooth extraction a physiologic resorption of the labial alveolar bone takes place. This often results in a tendency to place the implant more lingually to engage the available bone (26). Even with the use of tissue augmentation procedures, the emergence profile of the final implant-supported restoration may not be identical to that of the tooth that is being replaced (Fig. 11.2).

The profile of the crown of the natural tooth is also related to the level of the soft tissue. Therefore, for an implant restoration to appear natural and harmonious, a symmetric emergency profile should be achieved (27). This profile, in large part, is dependent on the soft-tissue biotype. Thus, surgical and restorative treatment planning must be different in cases of thick versus thin biotypes (26, 28). In patients with thin tissue, a connective tissue graft is frequently recommended to increase the volume of the tissue, before or during implant placement. These procedures will often prevent the exposure of the implant surface by making the tissue less likely to recede (29, 30). The potential for the gingiva to recede is also related to improper coronoapical and buccolingual orientation of the implant, and is dependent on type, size, and design of the implant and prosthetic component (Fig. 11.3).

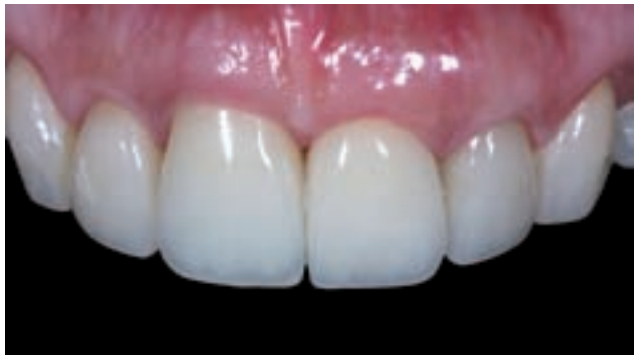


Fig. 11.2 Implant-supported restoration on tooth 8 with different emergence profile compared with all-ceramic crowns on teeth 7, 9, and 10.

Incorrect three-dimensional position

One of the reasons for an unesthetic implant-supported restoration is the incorrect three-dimensional (3D) positioning of the fixture (18). Even with the development of esthetic abutments and all-ceramic systems, it is still soft-tissue architecture, which is influenced by bone anatomy, that dictates the restorative result (31). To obtain a successful and predictable restoration, the first step is to establish an adequate bone and harmonious soft-tissue architecture. Implant design, position, and angulation are additional and important factors that must be considered before surgery (19).

At the beginning of the "modern era" of implantology, a limited number of implant options was available. With the development of the biologic, prosthetic, and esthetic concepts, many implant and restorative components are currently available (Fig. 11.4).

Regardless of the system, the implant shoulder should be placed in a coronoapical position 2–3 mm from the anticipated gingival margin position. However, because of the various implant design options, the clinician should determine the final position of the implant restoration before determining the apicocoronal position of the implant platform or the microgap between implant and prosthetic component. Before implant placement a diagnostic wax-up should be used to determine the ideal position of the final margin of the restoration. Three

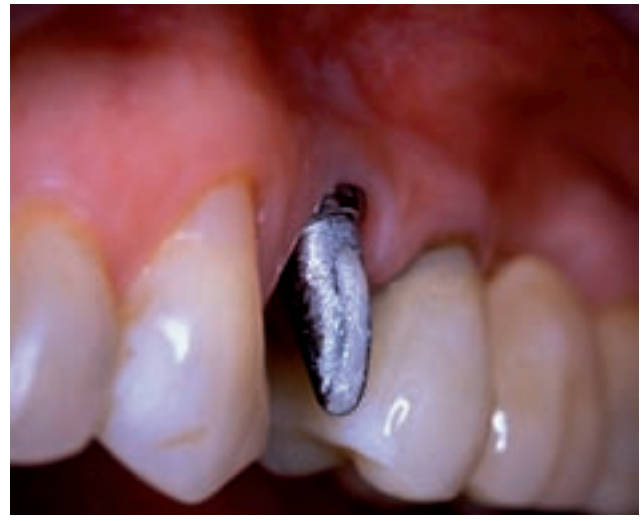


Fig. 11.3 Implant in a position that is too facial and does not allow the final abutment and the restoration to present an adequate emergence profile.

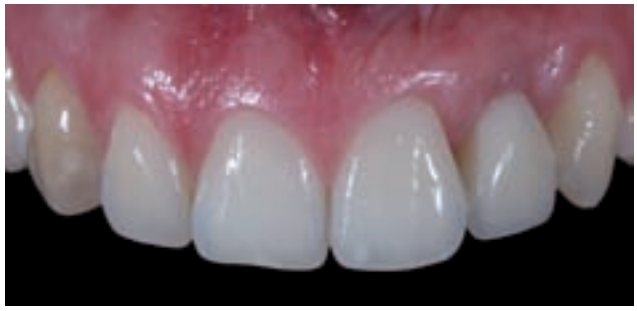


Fig. 11.4 A 3.3 mm (narrow neck) Straumann implant replacing the left lateral incisor (tooth 10) showing a different final tooth position and a grayish area. Owing to limited prosthetic component availability for this diameter there are no options available to customize an abutment for better tissue response and emergence profile.

casts are usually used for this purpose: one representing the initial situation, one for the wax-up, and another one for temporaries. Based on the wax-up a stable surgical guide is made. This surgical guide must have the final contour of the restoration showing the surgeon the position of the implant platform (Fig. 11.5).

For single unit implants, the surgeon must have a clear idea of the final treatment plan developed by the restorative dentist, as well as the location of restorative margins already present, or those which will be prepared on teeth adjacent to the implant restoration. It is important to achieve long-term tissue stability to avoid problems that can result in esthetic complications.

Proper 3D implant positioning also requires that the proper distance be available mesiodistally. The minimum mesiodistal distance required for a standard 4 mm implant is 7 mm (32). This will allow a 1.5 mm distance on each side to compensate for biologic width formation. With narrow diameter implants (≤ 3 mm) the minimum distance should be 5–6 mm (33). During the surgical phase the clinician must consider two important factors:

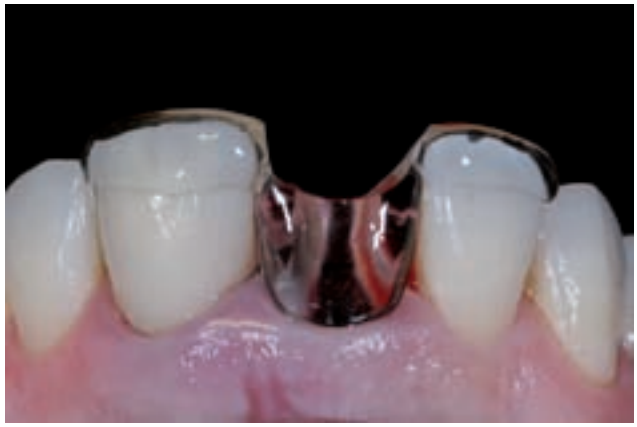


Fig. 11.5 In this case an implant was planned for tooth 8. Note that the gingival margin was maintained at the level planned on the radiographic and clinical evaluation. The surgical guide made on the first cast was based on the gingival margin waxed on the second cast. Note the location of the gingival margin on the guide.

the type of restoration, screwed or cement-retained, and the occlusal pattern. This impacts on the tooth position in terms of the anterior and canine guidance, and its function in a stable occlusal position. This factor is important even when selecting the type of implant to use. Let us hypothesize about a patient with a missing canine and intact dentition. For example, if canine guidance is maintained, all the stress will be absorbed by the prosthetic connection. Regardless of whether an external or internal connection is used, both types would be more susceptible to problems in the implant–restoration connection. When this scenario is present group function is preferred. There are two ways to analyze whether cement- or screw-retained implant restorations should be used. First, consider the retrievability of the system: if there is an abutment screw loose, a ceramic fracture, or an alteration to natural dentition next to the implant making a difference in shade, the crown may be removed and repaired without major problems. Second, if the abutment is frequently connected and disconnected, it may disturb the tissue complex around the implant, causing recession or damage to the surrounding anatomy (34, 35). Both of these factors must be considered in conjunction with the occlusion. If a large amount of bone is present with a perfect and stable occlusion both options are valid; however, if there is a pre-existing crown adjacent to the tooth being replaced, signs of unstable occlusion, or limited interocclusal distance, a retrievable option should be considered first, because if there is a potential problem, the clinician must be able to correct it easily.

A proper diagnostic wax-up and careful radiographic examination and surgical guide are all necessary to place the implant correctly and avoid excessively buccal or palatal positions. An implant placed too facially may cause additional resorption of the buccal plate, which in many cases makes it impossible to achieve the desired esthetic result (36).

If the implant is placed too far palatally, the restoration will require an overbuilt or cantilevered design significantly different from the natural emergence profile, with a resultant increase in plaque accumulation. This restoration also makes it difficult for the patient to clean the area adequately (Fig. 11.6).

The third position to consider is the apicocoronal placement, or how deep the shoulder of the implant must be placed for predictable results. Before determining this position, the clinician should analyze the neighboring teeth, and determine the restorative position in relation to the gingival sulcus. Moreover, the thickness of gingival tissue and periodontal biotype must also be considered. In general, the implant shoulder should be placed 2–3 mm apical to the planned buccal gingival margin. An apicocoronal placement of more than 3 mm from the buccal margin results in a deep sulcus that may

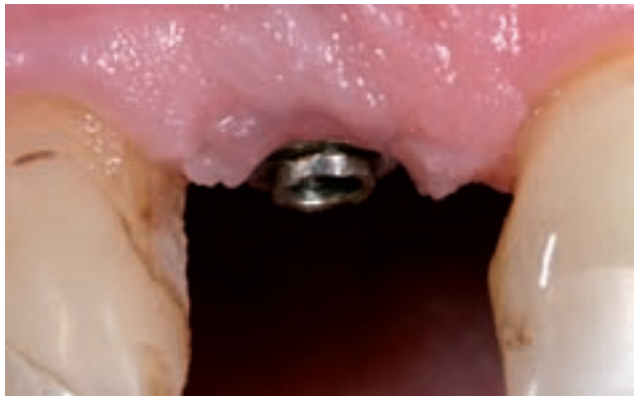


Fig. 11.6 The implant was placed without considering the apical coronal position. Note the fixture with almost no room to develop an adequate restoration.

become a problem for cleaning purposes, as well as for long-term tissue stability, since the peri-implant tissue responds to plaque formation in the same way, or more exaggeratedly, as gingiva would respond around a natural tooth (37). From a prosthetic point of view, if the crown–root ratio is not analyzed before implant placement it may create an overlong crown in the coronal apical direction, which may result in overloading of the prosthetic appliance. This initially could cause screw loosening and occasionally fracture of the abutment retaining screw or restoration. Implant restorations also suffer from ceramic fractures. In the authors' opinion, if a fracture occurs in an implant-supported restoration, it is easier with a screw-retained restoration to repair the veneering material. It is possible to remove the crown, place a temporary restoration, and make a new one or repair the previous restoration (38, 39).

Prevention and treatment of complications

The expectations of the patient should be defined and discussed at the initial appointment (6, 25, 40). Any issues should be re-evaluated and discussed during presurgical planning as well as during and after treatment.

With multidisciplinary planning, the surgical and restorative team has to evaluate the entire patient, and not focus only on the oral cavity. All esthetic facial parameters, occlusal patterns, and periodontal tissue type should be considered. After the initial analysis, all expectations and limitations should again be discussed before the final treatment planning (22, 40, 41). The patient must be made aware of alternative options and be informed about the steps of the proposed treatment sequence. In addition, the risk of failure due to biologic factors and patient habits must be discussed (21). In spite of appropriate diagnosis and treatment planning, complications may occur. These include loss of the interdental papilla, gingival recession, exposure of implant margins, chronic inflammation, bone loss, and prosthetic problems (6, 42).

The next step is to determine the esthetic zone for the patient. This depends not only on traditional classification that considers the anterior maxilla the most critical area but also on careful analysis of the complete oral cavity, taking into consideration esthetic and facial parameters such as the smile line.

Adequate presurgical treatment planning is necessary for any type of implant placement, in order to deliver a satisfactory restoration to the patient. From a technical point of view, unsatisfactory implant placement and a subsequent unacceptable restoration not only may result in legal problems for the dentist (21), but can also dramatically change the course of therapy, converting a single-implant restoration into a complex problem that is difficult to resolve.

In order to fulfill all the parameters for obtaining an esthetic restoration it is recommended that a checklist be created. If any of these parameters are found deficient, they can be analyzed, planned, and discussed with the patient before the implant placement.

When the clinician faces a complication involving an implant in the esthetic zone, the first step is to analyze the situation carefully, examining the mouth as was done before implant placement. The clinician must start with the patient's chief complaint. A digital photographic is indispensable for facial analysis as well as to determine the patient's smile line. A clear and high-quality image is important to develop a treatment plan and to discuss the patient's specific needs. Another option is to film the patient from different directions, talking and smiling (Fig. 11.7). With this information it is easier to review the critical characteristics of each specific case.

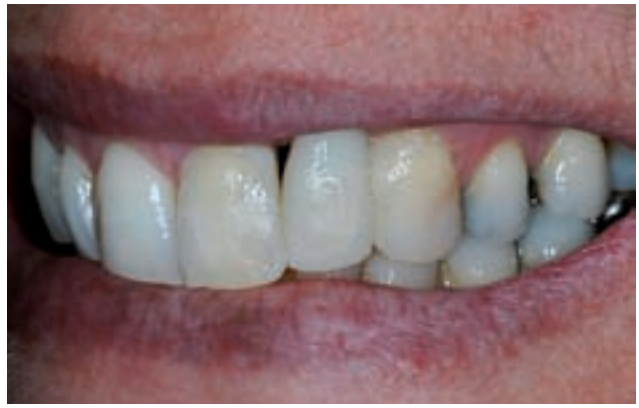


Fig. 11.7 Side view of a smile. The inadequate apically positioned implant in a patient with a high smile resulted in not only one, but several problems, including lack of papilla, an overlong crown, and a severe discrepancy that is impossible to correct without removing the implant.

Prevention of complications

Study models should be made, followed by clinical and radiographic examination of the existing teeth, either natural or modified by restorative and implant therapy. A checklist modified by Adolfi (43) (Fig. 11.8) is suggested to analyze all considerations and aspects for an esthetic and harmonious restoration. The following parameters should be addressed:

Esthetic checklist

1. Smile lip line.
2. Gingival levels.
3. Height of gingival contour.
4. Shape of gingival contour.
5. Zenith of gingival contours.
6. Texture and color of gingiva.
7. Osseous contour.
8. Mesial and distal papillae.
9. Interdental closure.
10. Interproximal contacts.
11. Midline, symmetry axis, and tooth axis.
12. Morphology, proportion, and basic shape of natural teeth.
13. Tooth color.
14. Interincisal angles.
15. Incisal edge position.
16. Incisal edge configuration.
17. Surface texture and surface gloss.
18. Implant tridimensional position.

The patient's chief complaints are generally associated with a high lip line in which tiny gingival disharmonies are readily noticeable, whereas most patients with a low lip line are less concerned about gingival architecture considerations. The proposed checklist is applied in all cases as part of a protocol to obtain a natural result. From a practical point of view, the following checklist topics are essential and may help the clinician in fabricating an initial treatment plan or in treating complications that may arise.

Smile or lip lines

Among all parameters, the smile line is the first to be analyzed and depicts the relationship between lips, teeth, and gingival tissue. Depending on the exposure of the anterior teeth and gingiva, the number of procedures necessary to reach a desirable result or solve a problem may be anticipated. In a classical article by Tjan *et al.* (44) a classification of smile line was proposed taking into consideration the anterior maxilla. A low smile line exposes no more than 75% of the anterior teeth, thus exposing no gingival tissue. The average smile reveals from 75% to 100% of the anterior teeth and papillae. In the average smile, with the lip in forced position (maximum labial movement), it is possible to visualize not only the teeth, but also the interproximal gingival tissue. A high smile line shows the entire anterior teeth, (the total incisal–cervical length) the entire papilla, and buccal gingiva. With a careful analysis of the patient's smile much information can be obtained and used as an important diagnostic tool during the initial consultation (41). Extraoral photographs are also very helpful for treatment planning.

After extraoral analysis, the intraoral examination will track problems, such as a lack of papillae; from the clinician's point of view this is important even if the patient presents with a low lip line.

Mesial and distal papillae

Papilla management in dental implant therapy is a well-documented issue in the current literature (12, 26, 45–49). Before the implant is placed, it is possible to predict whether the papilla will be present or not, based on the distance from the bone on the adjacent tooth to the contact point. However, when the implant is already in position it becomes quite difficult, or at times impossible, to correct a deficient papilla. The interdental papilla may be defined as the portion of the gingiva that occupies the space between two adjacent teeth. Clinical concerns regarding black spaces between teeth are an issue that has been discussed at length and many techniques have been suggested for correction. The classical article published by Tarnow *et al.* (12) discussed the factors critical to papillae height between teeth and led other investigations to evaluate and analyze why the papilla is present or absent around implants. Grunder *et al.* (18) reported that the papilla between a tooth and an implant is always present when the distance between the bone on the tooth (mesial or distal to the implant) and contact point is less than 5 mm. In reality, in this study, the critical distance averaged 4.2 mm. Another factor to consider is the distance between tooth and implant. If the distance is less than 1.5 mm, bone interproximal resorption may occur and the papilla will recede. Again, in a patient with a low lip line it is possible to mask this situation by widening the final restoration, or adjusting the neighboring tooth, or doing nothing if the patient is satisfied with the result. However, in cases of tissue deficiency, pink composite or ceramic tissue prosthesis can be used (25). This procedure avoids surgical correction to restore the papilla, which is not predictable when an implant is already in place (48).

Long axis, morphology, proportion, and basic shape of natural teeth

When a missing tooth is to be replaced by a dental implant, the goal is for the final anatomy of the crown to

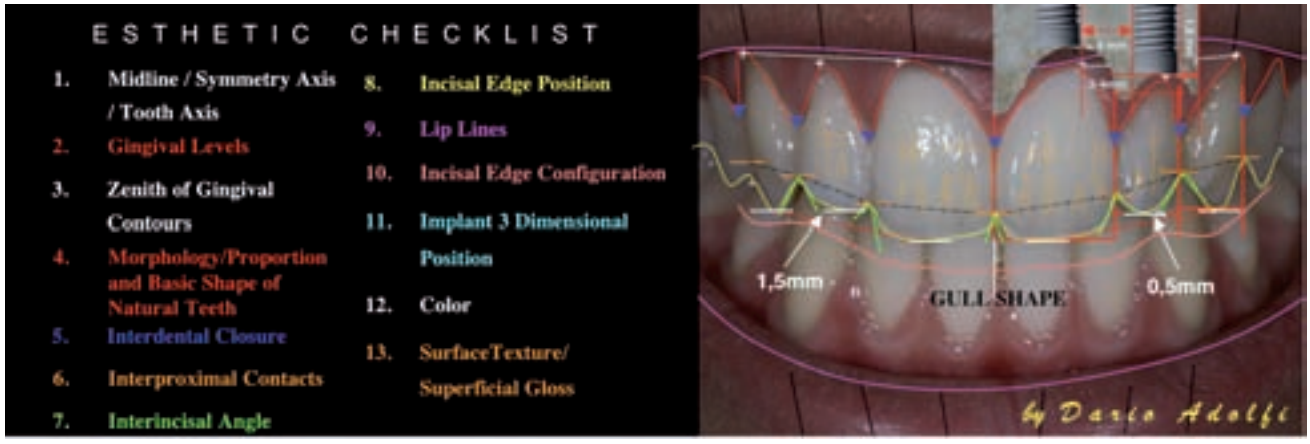


Fig. 11.8 Esthetic checklist modified by Adolfi (43).

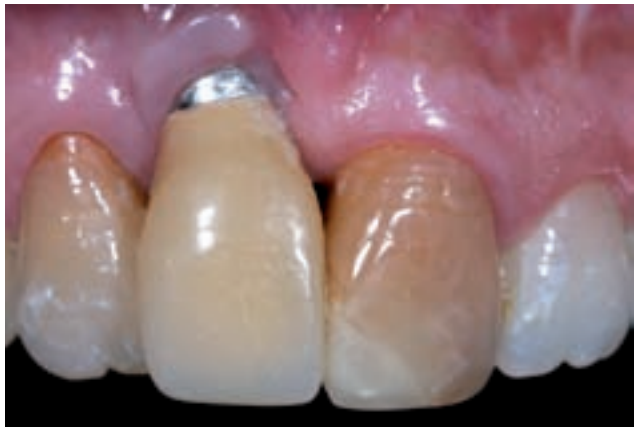


Fig. 11.9 An example of an inadequate final restoration. In this case the treatment planning did not include the other teeth, and the final result would only match if the other teeth were restored. Moreover, the inadequate implant position results in more than one problem.

be in harmony with the soft-tissue architecture. However, the number and complexity of the procedures should be assessed and discussed with the patient in advance. As a starting point, the clinician must use the study casts or wax-up to shape the ideal form of the tooth that fits into the edentulous area (31). When the space is not adequate for the ideal tooth design, the clinician should anticipate that the final restoration will be a compromised result.

At that time, the laboratory technician plays a very important role, because the final tooth position can be anticipated using the wax-up. This must be determined before making any clinical decisions (Figs 11.9 and 11.10).

High gingival levels and shape of osseous contours

The periodontal soft-tissue architecture depends on the bone contours (50). If a patient has deficient papillae, the interproximal bone levels and gingival contours are at a more apical location than normal. This may be the result of too close a proximity of the implant to the root of the adjacent natural tooth (18, 23, 50, 51). When an implant is already in place, closing the black triangle with a prosthetic solution may not produce an acceptable esthetic result. Kois (51) noted that many dentists think that just by adding materials on the retained implant crown this problem is solved, but this is a critical mistake. Guided by the restorative dentist, the dental technician can develop the ideal dental restoration and the relationship between the patient's gingival tissue and the area surrounding the implant (19, 25). The facial and lingual surface of a restoration should not be excessive because this may interfere with adequate plaque removal, which may cause gingival inflammation. The use of a stone cast will help in determining the most adequate interproximal contour, taking advantage of all available techniques. However, sometimes it is impossible to solve this problem, because an implant cannot be moved, as can be done with natural teeth using orthodontic treatment (13, 14). When it is not possible to correct a severe error made during the initial surgical procedure, removal of the implant should be considered (Fig. 11.7) (see Chapter 25). Sometimes even after careful evaluation, expectations may not be reached because the gingival tissue contour may have been altered during the impression or temporary procedures and may not exactly replicate the normal gingival architecture. To avoid severe alterations, the bone architecture of the natural dentition should be evaluated, to determine the inherent limitations. Before final restoration, the patient should be informed of any biologic limitations present and understand how they will affect their treatment.

Texture and color of gingiva

A careful analysis of the gingiva must be made before treatment. When the clinician deals with a single implant, the color differences between the soft tissue around the implant and the natural teeth often become a problem,

even when the shape and shade of the restoration are similar to those of the natural dentition (52). The same shine-through effect in metal ceramic restoration and cast metal post and core systems can also occur around implants. It is important that this possibility be considered before implant placement. Depending on the thickness of the buccal plate of bone and the gingival biotype it is possible to foresee this complication. Careful evaluation of the tissue and digital photography are helpful. The clinician can predict whether it will be possible to match the color of the natural dentition and the surrounding implant tissue. This complication is quite difficult to correct (Fig. 11.11).

Prevention of single-implant complications

Clinical applications of the esthetic checklist

A clinical case is presented to show how to apply the esthetic checklist for two single implants.

During the first consultation a complete clinical examination was performed, including impressions for study casts, bite registration, occlusal records, photographs, taking the shade of the natural dentition, and analysis of intraoral and extraoral health. In addition, a full set of radiographs was obtained and computed tomography (CT) was carried out for a better understanding of the true clinical situation. The initial situation is shown in Fig. 11.12.

In the anterior maxilla, at least eight pictures were used to determine the best treatment planning: 1: front smile forced position; 2: right lateral smile; 3: left lateral smile; 4: dentition in maximum intercuspation (with lip retractors); 5: canine to canine with lip retractors; 6: right lateral with retractor, with the lateral incisor in the center of the picture; 7: left lateral with retractor, with the lateral incisor in the center of the picture; and 8: occlusal view picture with a mirror.

At this time the dental team explored the patient's expectations. (In every dental implant treatment it is important to emphasize limitations with regard to biologic aspects and the total length of the treatment.)

With all the information in hand the dental team, surgeon, restorative dentist, and dental technician carefully analyzed the case.

The morphology, proportion, and shape of the desired final tooth, as well as the interproximal contacts and interincisal angle, were first determined.

After the most appropriate tooth was defined for the edentulous area, the 3D position of the implant was determined (Fig. 11.13).

The radiograph and CT scan were then evaluated to check whether there was sufficient bone thickness and height to place the implant in the adequate position.

After the entire treatment had been explained to the patient, the implants were placed, together with a connective tissue graft.

An immediate provisional was placed (Figs 11.14 and 11.15). A waiting period of 6 months was required to evaluate the results of the provisional phase.

At the time of re-evaluation the results showed that it was possible to proceed with the final restoration.

An impression of the head of the implant was taken, using the temporary restoration as an impression coping. Although this technique requires more time, it is possible to duplicate the exact position of the gingival tissue. It was then possible to design the final restoration on the cast, because every detail of the restoration and the implant position was determined before implant placement.

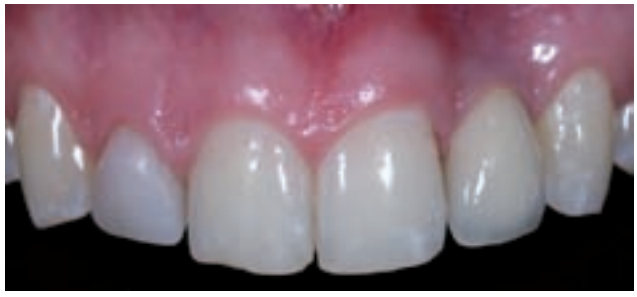


Fig. 11.10 An implant-supported restoration on tooth 10; the improper fixture position was a cause of an inadequate tooth position, with dimensions that do not fit in the space of a lateral maxillary incisor; besides, there is a critical lack of soft tissue in the facial wall creating a gray shade depression.

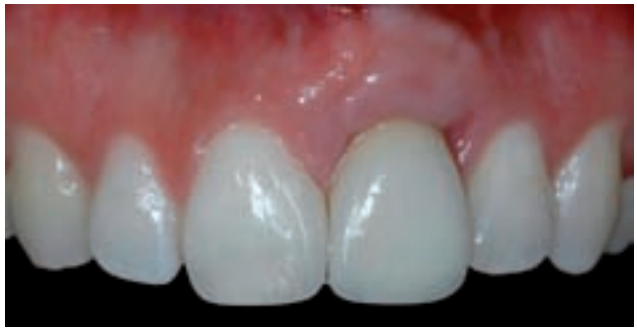


Fig. 11.11 A final restoration with a scar as a result of a free gingival graft.

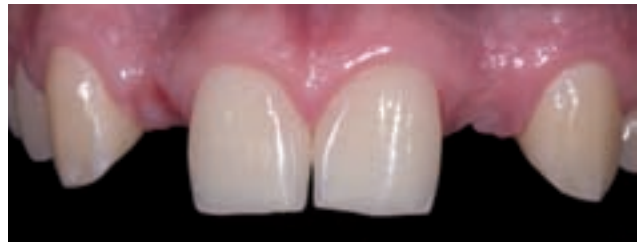


Fig. 11.12 Initial situation of the two missing lateral maxillary incisors.

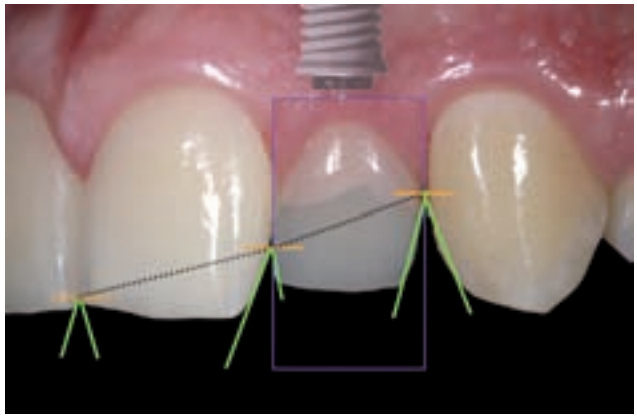


Fig. 11.13 The tooth dimension and position were first determined, followed by the apical implant position and details of the interincisal angles.

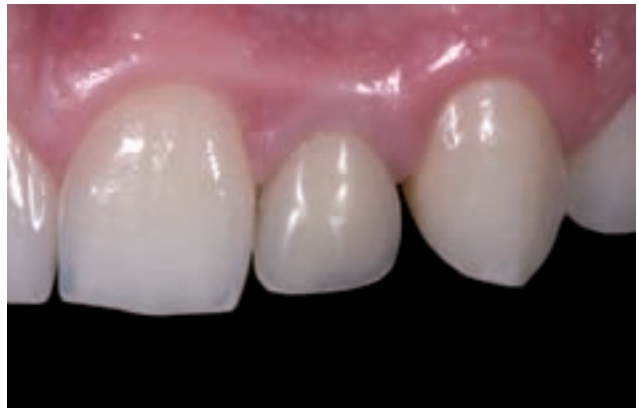


Fig. 11.15 View of the temporary restoration on implant tooth 10, 6 months after the first stage of surgery.

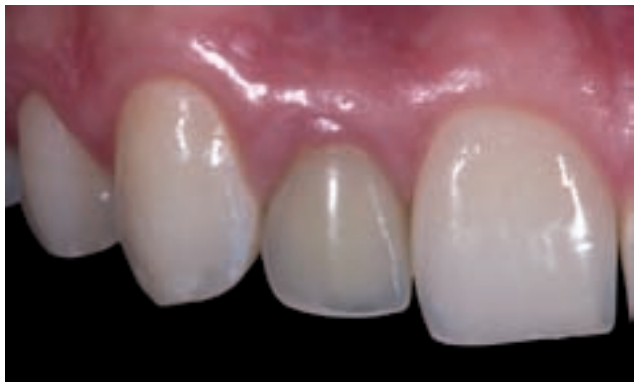
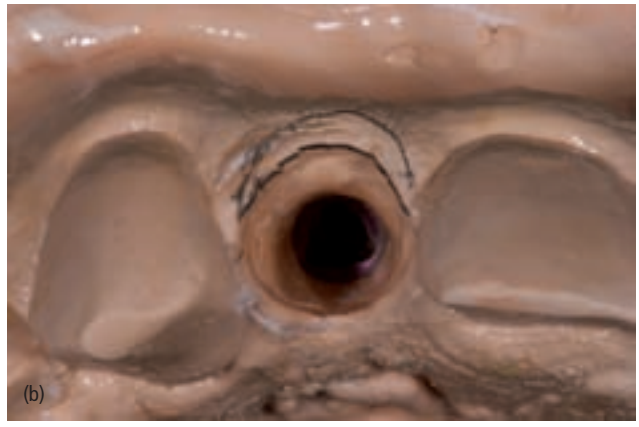


Fig. 11.14 View of the temporary restoration on implant tooth 7, 6 months after the first stage of surgery.



Figs 11.16 (a, b) On the final cast it was possible to determine the area that required removal to allow a better and more natural profile.

Based on the previous treatment planning with the final cast in hand, the dental technician removed the temporary restorations and reshaped the desired position of the restoration on the stone cast. Knowing the apical position of the implant, the emergence profile could be reshaped at this time (Fig. 11.16a, b).

The final abutment was waxed on the modified cast, in accordance with the previous initial treatment plan.

A customized Procera (Nobel Biocare) abutment was produced in zirconia (Fig. 11.17) and customized with a compatible ceramic to support the soft tissue (Fig. 11.18). It is extremely important to note that most of the time the abutment presents an emergence profile that needs to be customized to build a crown without overcontour (Fig. 11.19). With the help of a compatible veneer zirconia ceramic (Nobel Rondo Zr, Nobel Biocare), a new margin was designed and the convex surface was shaped in a concave manner to create a thicker soft tissue around the abutment, allowing a better emergence profile of the final crown (Fig. 11.20). This also allows the marginal gingiva to grow coronally.

Since the implant was in the correct 3D position, it was possible to modify the abutment to design the most suitable profile. Thus, a customized Procera crown was delivered to the patient (Figs 11.21–11.23).

Laboratory applications of the esthetic checklist

The multidisciplinary approach of the esthetic implant protocol must be applied in the laboratory as well. With all the tools in hand the dental technician follows the same items as those of the esthetic checklist.

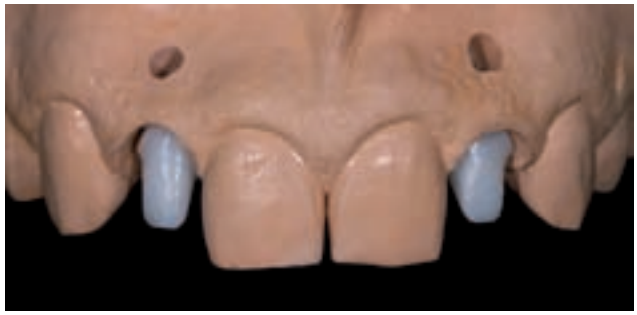


Fig. 11.17 Alumina Procera abutment in position on teeth 7 and 10.

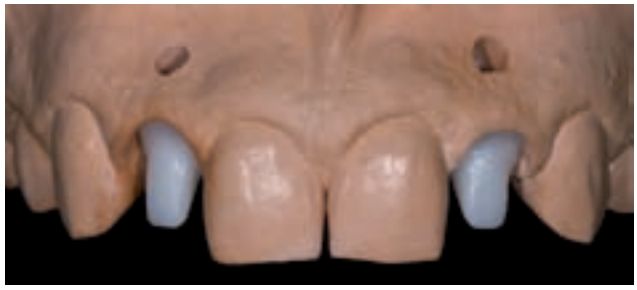


Fig. 11.18 Customized abutment just after being modified with a compatible ceramic.

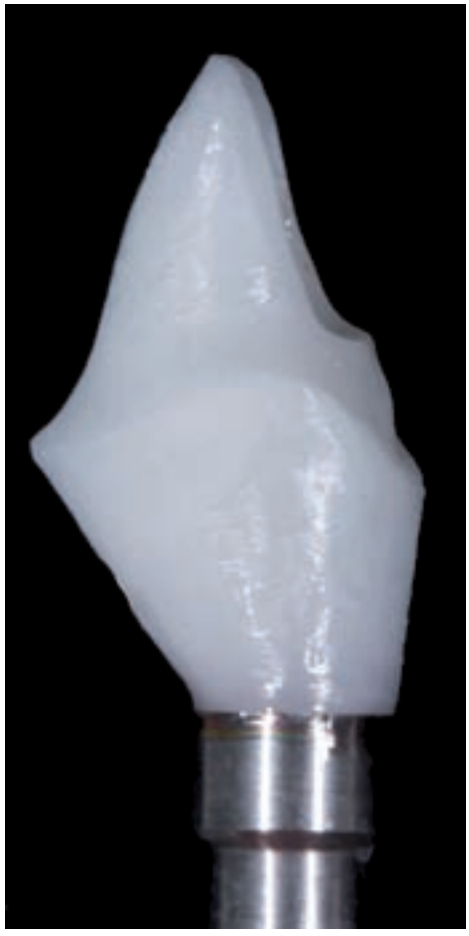
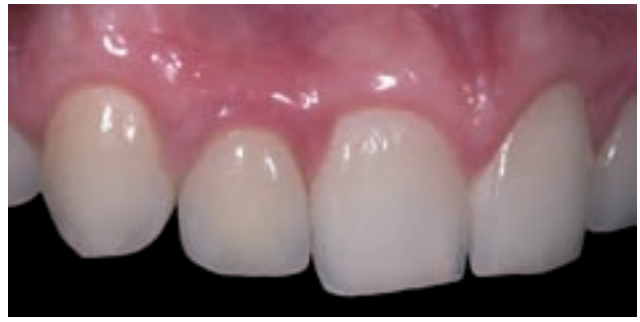
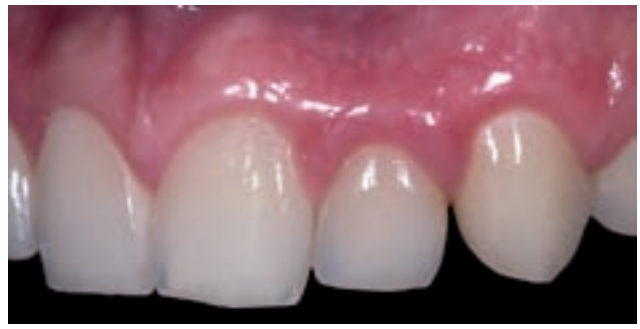


Fig. 11.19 Customized abutment in the original shape.

Fig. 11.20 The abutment, after the modification to develop an adequate support to the soft tissue.





Figs 11.21 and **11.22** View of the final Procera Alumina crowns cemented on the customized zirconia abutment.

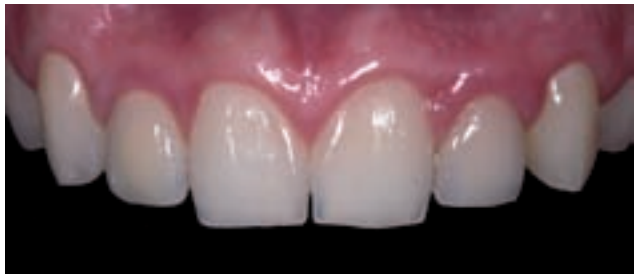


Fig. 11.23 Front view of the final restorations.

To achieve an outstanding result in the laboratory, the clinician must follow the same rules applied in the clinic. First, the quality of the photographic documentation should show the clinical situation as closely as possible to the one in the patient's mouth, because without communication among the members of the team, there is no link between them.

Another important factor is the choice of the impression material, since this will also affect the final result. An implant restoration requires the same accuracy as fixed bridge work. Thus, the materials must allow the technician to obtain more than one model for the same impression; and this is only possible with polyether and polyvinyl siloxane. The materials used in the laboratory, including stone, plaster, wax, pattern resin, and others, must be manipulated with respect to the properties of each material.

When the lab technician has all the information, he or she can develop the most adequate and suitable restoration for the case.

Clinical applications of the esthetic checklist

Orthodontics as an adjunct

The following case included orthodontics before tooth extraction to obtain an improved esthetic implant restoration.

The patient presented with a fractured central incisor (tooth 9), which required extraction. The checklist was applied, analyzing all the aspects of the natural dentition as part of implant planning. The gingival contour was not ideal and the mesial and distal papillae, although present, were not esthetically acceptable. The neighboring teeth also had large composite restorations, which needed to be replaced. All of the above were considered as part of the final treatment plan. Everything was explained to the patient and orthodontic extrusion was proposed to bring the soft tissue and the bone into a more coronal position. The procedure is described in Figs 11.24–11.28. In this sequence it is possible to perceive that in conjunction with the implant placement the clinician has to consider the entire scenario and establish the best treatment sequence.

Single anterior implant associated with a porcelain-fused-to-metal crown

Before implant placement, if the adjacent teeth have full crowns that require replacement, a three-unit provisional should be constructed in conjunction with atraumatic extraction of the hopeless tooth. The advantage of this technique over immediate implant placement is that

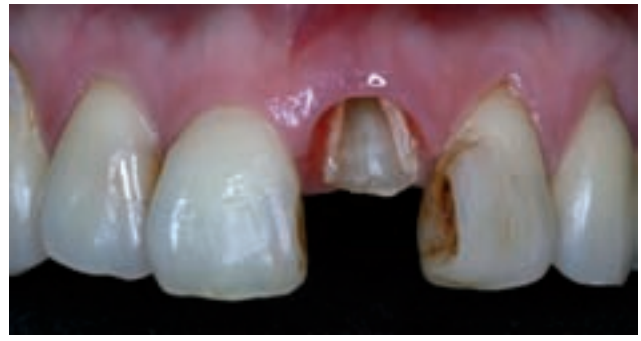


Fig. 11.24 Tooth 9 with a fracture of the vestibular wall of the root. It is possible to see that there was no harmony of the tissue and bone of tooth 8.

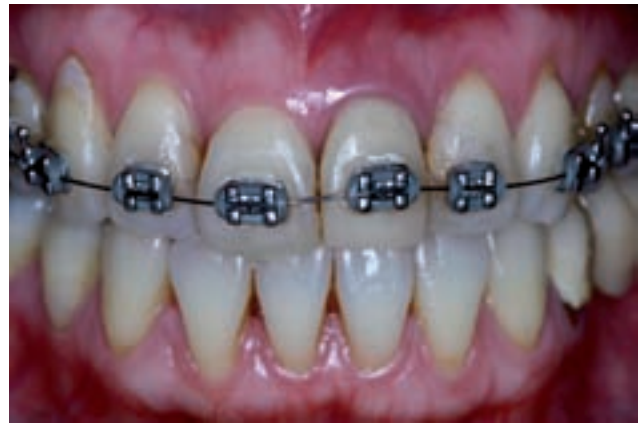


Fig. 11.25 Initial situation before the orthodontic extrusion. A composite resin post and core was made and a composite resin temporary restoration placed, and cemented with resin cement. The orthodontist had mounted the brackets in place to start the movement.

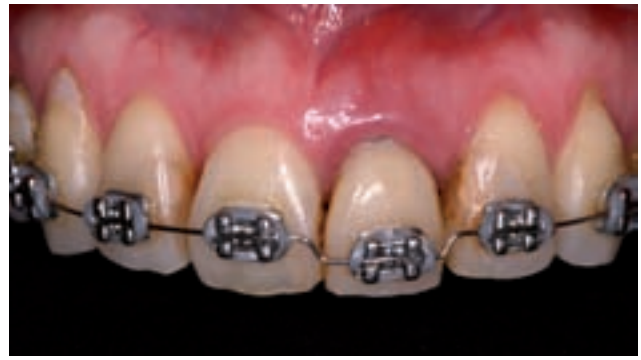


Fig. 11.26 After 8 months of treatment, it was possible to note the more coronal position of the vestibular bone and gingival level. In this position the tooth was extracted and an immediate implant was placed.

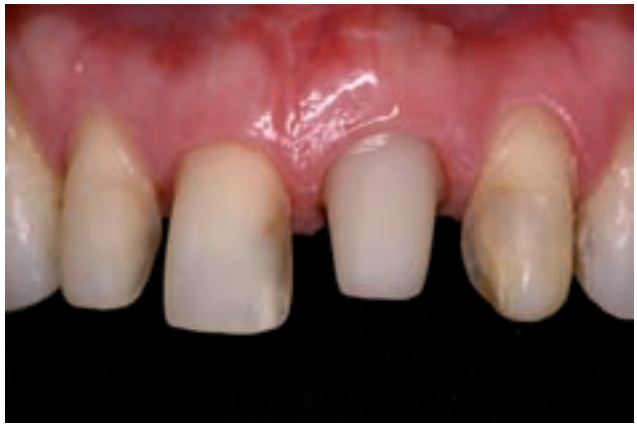


Fig. 11.27 Teeth were prepared for all ceramic bonded restorations associated with an implant-supported restoration on a customized esthetic ceramic abutment.

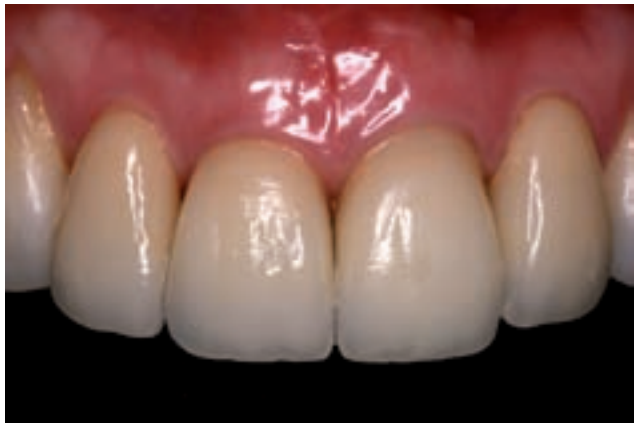


Fig. 11.28 Postoperative view of the final restorations 30 days after the final fixation.

it is possible to correct other factors that were detected in the checklist before implant placement, to obtain a successful esthetic result.

The proposed treatment was full-mouth rehabilitation. Tooth 9 was extracted as early as possible to avoid damage to the bone surrounding the area. After the extraction a fixed temporary restoration was placed, creating an ovate pontic design with a slight compression in the socket to maintain the clot and the gingival contour (Figs 11.29–11.32).

A connective tissue graft compatible with the size of the facial defect was taken from the palate. With the same access incision used for placing the implant, a split incision was made and the graft was positioned into the "tissue envelope" with the help of a suture cord. The connective tissue graft occluded the implant access. At that time the temporary restoration was reduced to prevent it from touching the graft area (Figs 11.33–11.37).

While the implant was healing the other areas of the mouth were prepared for restorative reconstruction. The

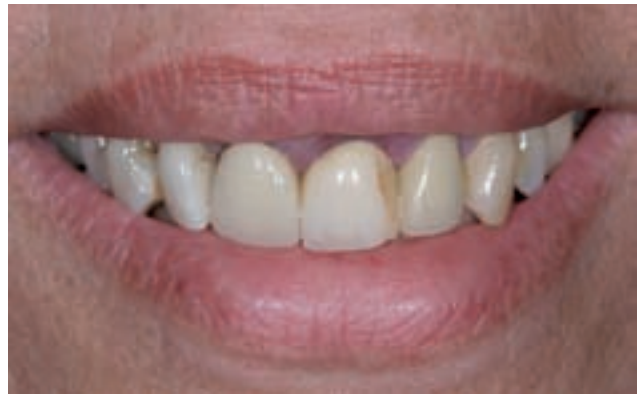


Fig. 11.29 A patient with a root fracture (tooth 9) also complained about the esthetics of the failed composite restorations. In the extraoral picture it is possible to see that the midline is not in the most desirable position relative to the midline of the lips.

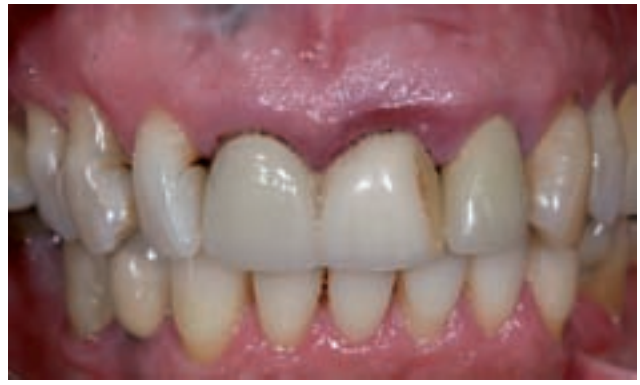


Fig. 11.30 In this photograph with the lip retractor it can be seen that there was severe retraction, absence of the right upper canine, and large restorations. When analyzing the two pictures, note that the concern was not about the implant or technique that should be used, but rather how to deliver the most adequate fixture that matched the anterior restorations and looked as natural as possible.

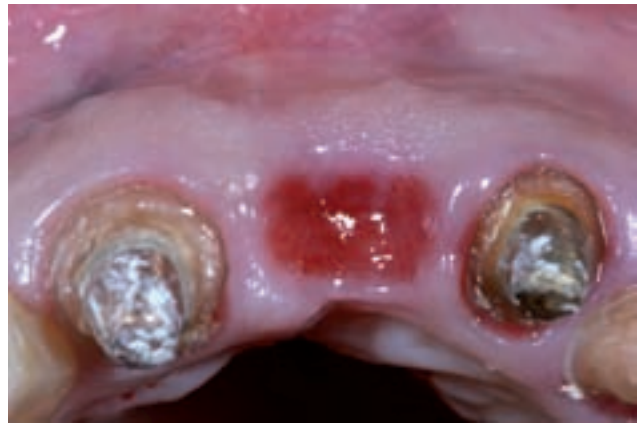


Fig. 11.31 Occlusal view after 60 days, following the extraction of tooth 9, without the temporary restoration. In this view of the extracted tooth area, it is possible to see that even with the pontic stabilizing the tissue, it was not the same as when the tooth was present.

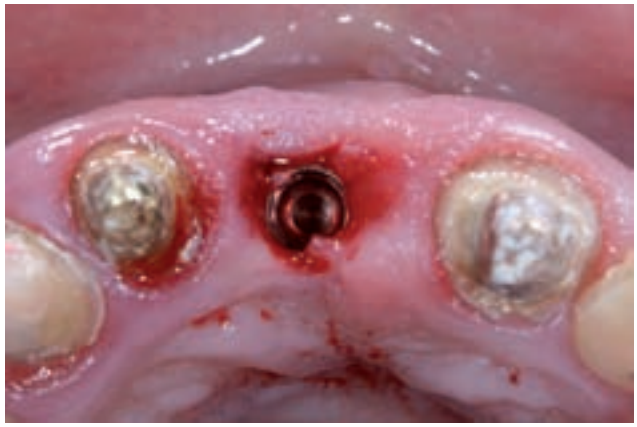


Fig. 11.32 The implant was placed in a slightly palatal position with a minimal incision in the position where the tooth had been. On the facial aspect, note that even with the implant in position, the facial gingival depression was still present.

Fig. 11.35 After impression, the final casts were obtained in stone and the emergence profile was defined, based on the diagnostic wax-up and the first set of temporary restorations. As a tissue conditioner, whenever possible, the authors prefer a screw-retained restoration that is easy to modify to obtain the most desirable emergence profile.

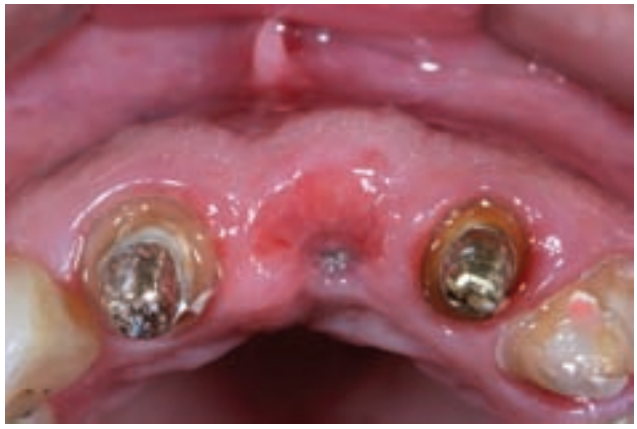


Fig. 11.33 Sixty days after the fixture placement and connective tissue graft, it is possible to see how much tissue was gained in the facial area.

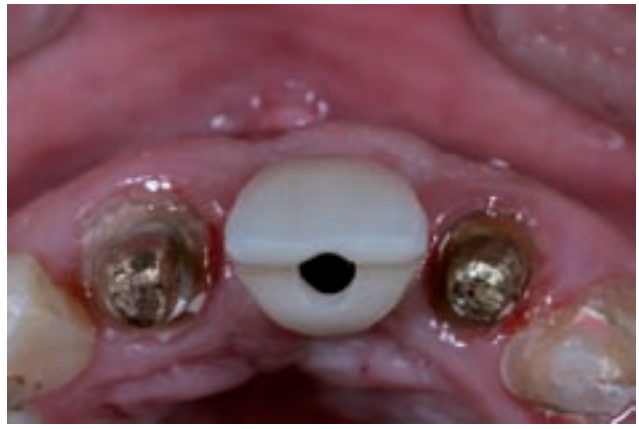


Fig. 11.36 Temporary restoration in position; note how the tissue is quite similar to the natural dentition. The second set should be as close as possible to the final anatomy and position with regard to the esthetics and occlusion.

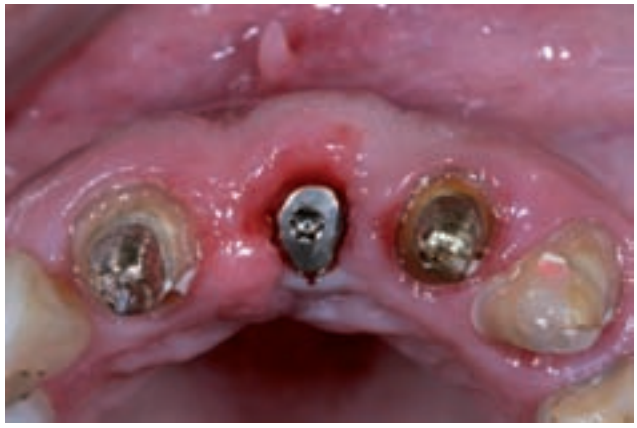


Fig. 11.34 Incisal view of the area just before the impression with the healing cap in position.

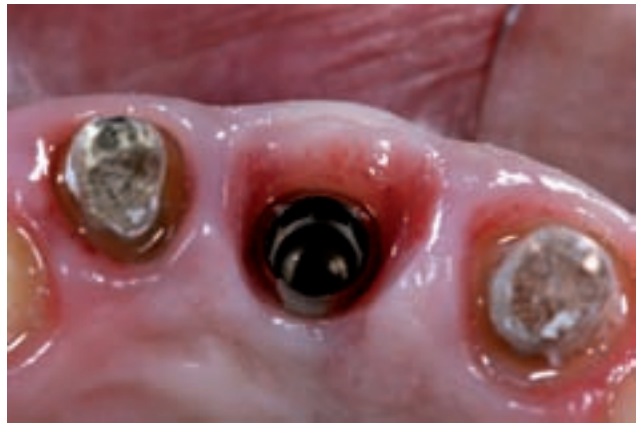


Fig. 11.37 After 90 days of tissue maturation it is possible to see the position of the soft tissue before impression procedures. The tissue anatomy was maintained through careful extraction procedures, tissue control, and correct implant placement.

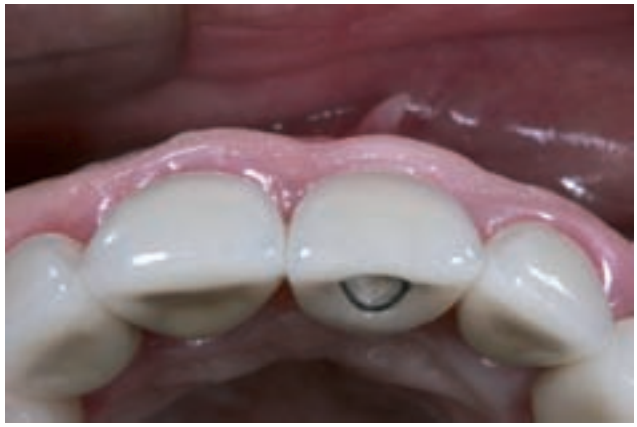


Fig. 11.38 Incisal view of the final restorations on anterior maxilla. The bone contour is similar when comparing the natural dentition and the implant area.

next step was to take an impression on the internal connection of the fixture to develop the emergence profile of the tooth as close as possible to that of the natural dentition. No incision was made; a plastic cap was put into place for the impression. For cases involving implants, polyether is an excellent option for impression material. A preliminary impression was taken for a new set of temporary restorations, which would correct the items that were not acceptable in the checklist (Figs 11.38–11.40).

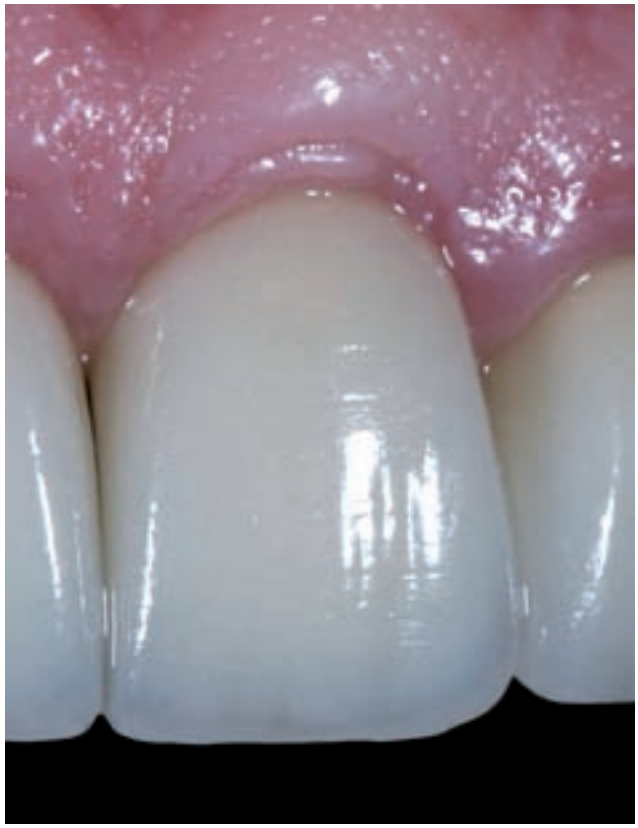


Fig. 11.39 Close-up view of implant-supported restoration 9. It is possible to visualize the scar as a result of the connective tissue graft in the area.

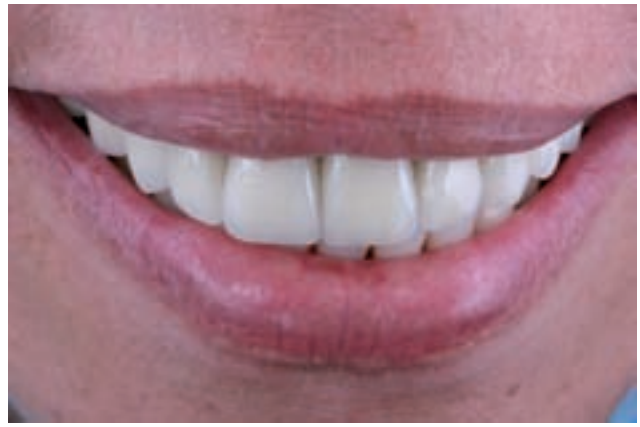


Fig. 11.40 Final result of the full-mouth rehabilitation. When the initial (Fig. 11.29) and final pictures are analyzed it can be observed that we must monitor the possible recession that may occur in the future, and try to keep the smile design at the level of the lip. This may require periodontal plastic surgery, monitoring, and appropriate treatment planning.

Single anterior implant associated with a partial laminate veneer

A single implant in the anterior maxilla is frequently associated with an intact dentition where there is a discrepancy in tooth morphology. The single restoration could not in itself correct this discrepancy. Restorative planning before implant placement is necessary for esthetic success (Figs 11.41–11.45).

Dealing with a failure

Immediate implant and temporary restoration placement is a safe procedure that may provide successful results in terms of tissue stability as well as comfort for the patient. However, as with any procedure in dentistry there may be problems and failures. A case with this type of complication is discussed (Figs 11.46 and 11.47).

After a careful analysis of the case, all the treatment options were explained to the patient, including the

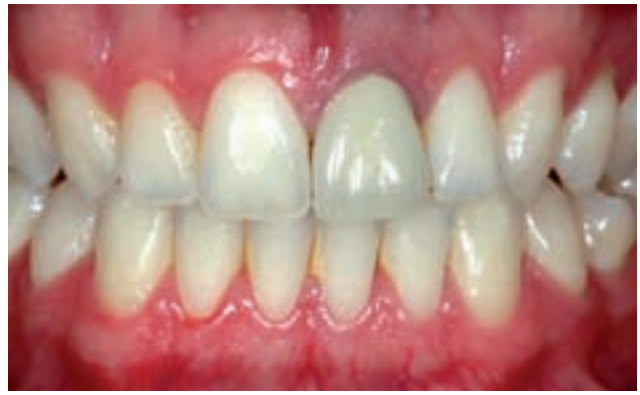


Fig. 11.41 Tooth 9, which will be replaced by an implant, would be too wide if the space of the edentulous area were not distributed to the adjacent teeth.

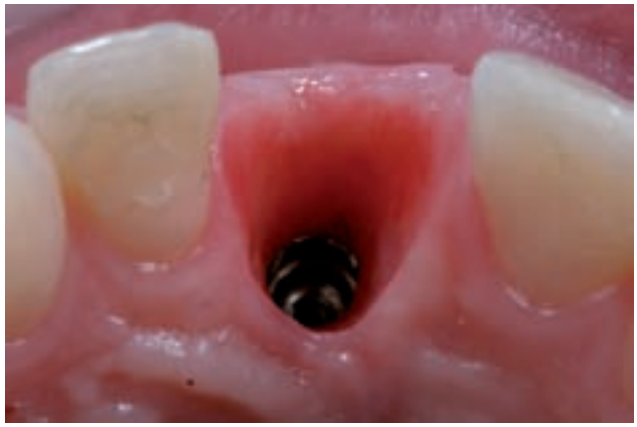


Fig. 11.42 After bone augmentation and two connective tissue grafts the emergence profile contoured by the provisional restoration is established.

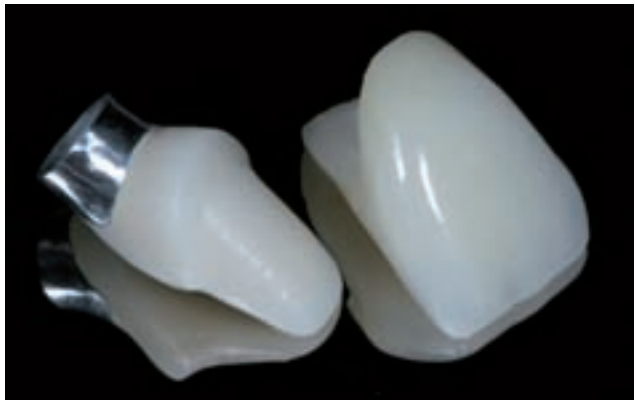


Fig. 11.43 A customized ceramic abutment was made associated with an all-ceramic crown.

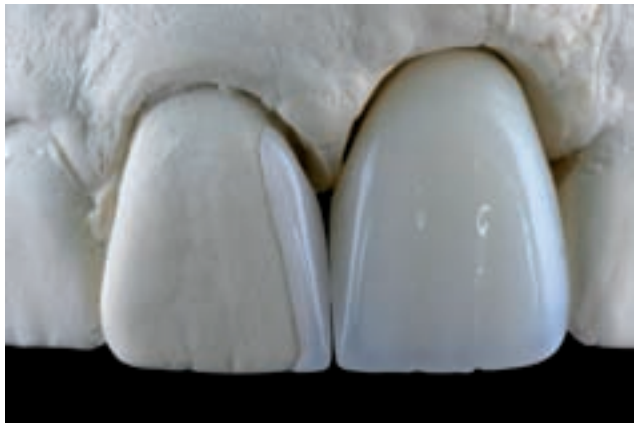


Fig. 11.44 Because the mesiodistal distance was not equal when teeth 9 and 8 were compared, a partial laminate veneer with no preparation, only etched to the enamel, was planned.

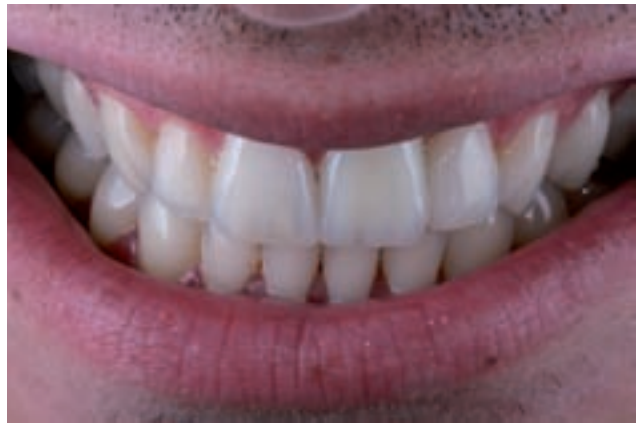


Fig. 11.45 Final results showing the patient's harmonious smile.

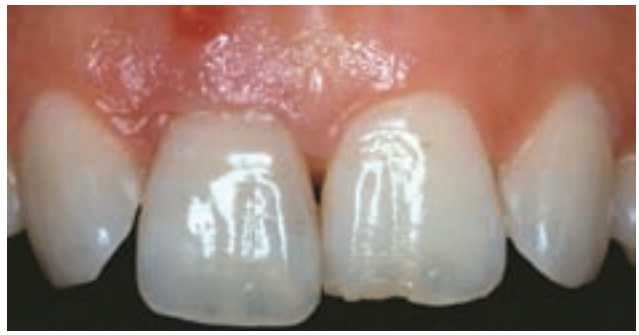


Fig. 11.46 A 28-year-old woman came to the office complaining of pain in tooth 8 during chewing, with esthetic concerns regarding shade differences between teeth 8 and 9. It is possible to see the fistula in tooth 8, and the initial presentation of the case.

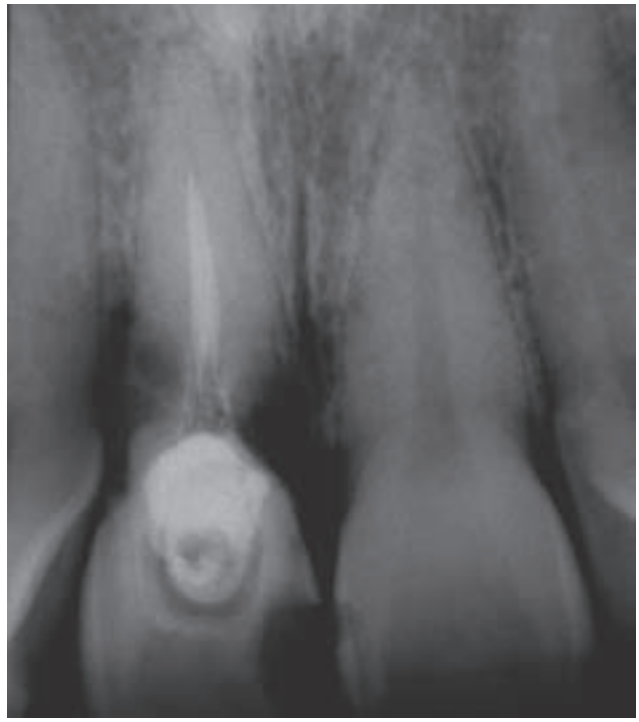


Fig. 11.47 The radiographic view of the clinical situation. It is possible to observe the external root resorption that indicated that the tooth was hopeless and required extraction.

differences between the traditional crown and bridge procedure and implant therapy. The option selected included implant therapy with immediate implant placement at the time of the extraction. Ten days of antibiotic therapy was prescribed before surgery and on the day of the procedure the fistula in tooth 8 was no longer present. The patient was previously warned that complications could occur, when it was explained that immediate implant placement was an option. The tooth was extracted, the socket carefully débrided and the implant placed, followed by an immediate non-occluding temporary restoration. Six months after the procedure the implant was lost, although no sign of infection was detected. The area was cleaned and allowed to heal for 60 days.

From a clinical point of view the procedure was a biologic failure. In addition, it covered a clinical complication, because the facial bone that had been present was now lost. A new treatment plan was then prepared, starting with bone reconstructive procedures, in which a chin bone graft was contoured and trimmed to fit the area. The bone graft was stabilized in place with screws. The space voids were filled with particulate bone graft (BioOss, Geistlich, Switzerland) and covered with BioMend collagen membrane (Zimmer Dental, USA) and a connective tissue graft harvested from the palate (Fig. 11.48).

An internal connection (AR Connection; Conexao, São Paulo, Brazil) 13 mm implant was placed, followed by a connective tissue graft to gain more soft tissue. At the time of the implant placement an impression of the connection was taken to prepare the temporary restoration. Six months after the fixture placement second stage surgery was performed and the temporary restoration put into place and allowed to heal for 4 months (Fig. 11.49).

The temporary restoration was used as a transfer instrument because it indicated the real position of the tissue. After a careful sequence of pictures for shade selection, casts were sent to the ceramist to prepare the final restoration (Figs 11.50–11.52).

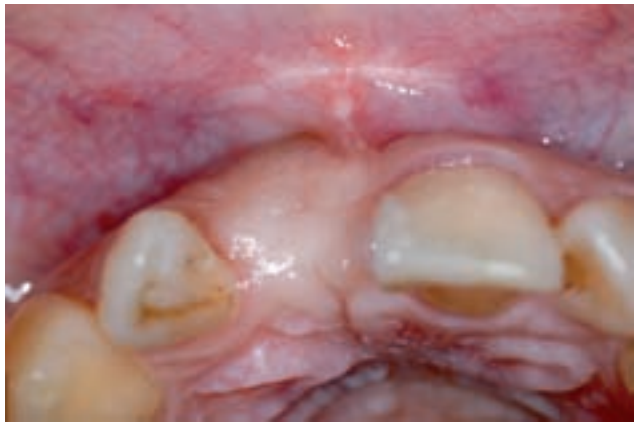


Fig. 11.48 In this incisal view taken 8 months after the bone augmentation it is possible to see that the area was amenable for ideal implant position

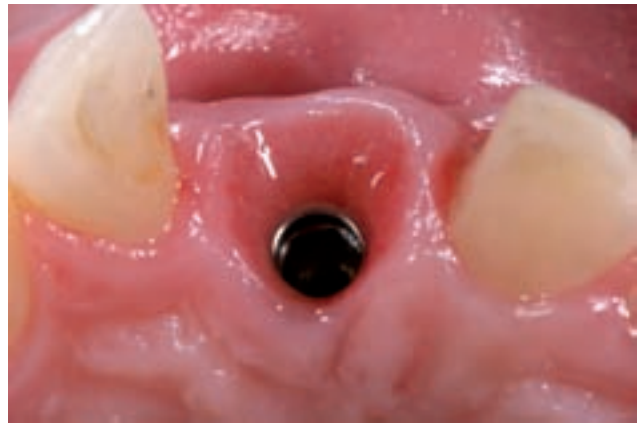


Fig. 11.49 The soft-tissue aspect at the time of the final impression. The design of the emergence profile was defined in the laboratory by the technician according to the clinician's treatment planning.

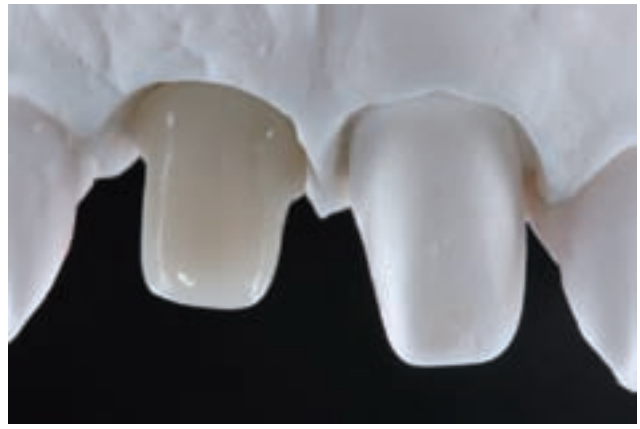


Fig. 11.50 To improve the final esthetic result, a laminate veneer was also planned on tooth 8. The abutment selected for the case was covered with a fluoride apatite-based ceramic (Emax Ceram; Ivoclar Vivadent, Liechtenstein). Thus both substrates had the same shade.

Fig. 11.51 Customized abutment for 9 implant restoration and all-ceramic crown (Emax Press/Emax Ceram; Ivoclar Vivadent, Liechtenstein). The advantage of using a customized ceramic abutment is that it is possible to use the same veneered ceramic as used for the veneer on the crown.

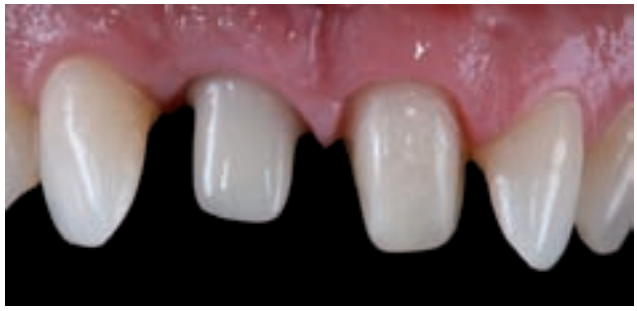


Fig. 11.52 Intraoral picture showing the customized ceramic abutment in place and the prepared tooth (no. 9) ready for final luting procedures.

For the luting procedures, as the ceramics were glass-based ceramic, they were etched with 9% hydrofluoric acid. Afterwards, the etched ceramics were cleaned in an ultrasonic bath immersed in distilled water for 5 minutes. The surfaces were dried and a silane agent was applied for 2 minutes and air-dried. A bonding agent was applied and the restorations were bonded with resin cement (Figs 11.53 and 11.54).

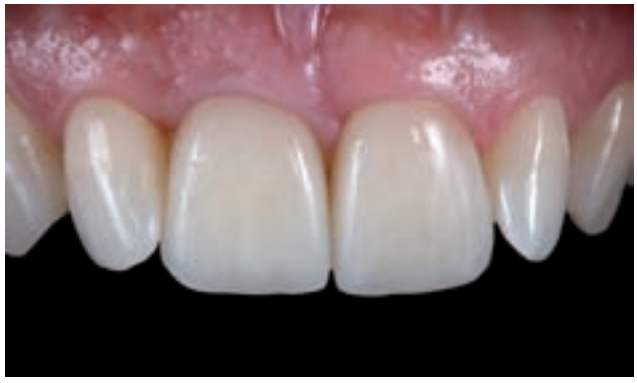


Fig. 11.53 Final result of the implant-supported restoration and the ceramic veneer after 120 days.

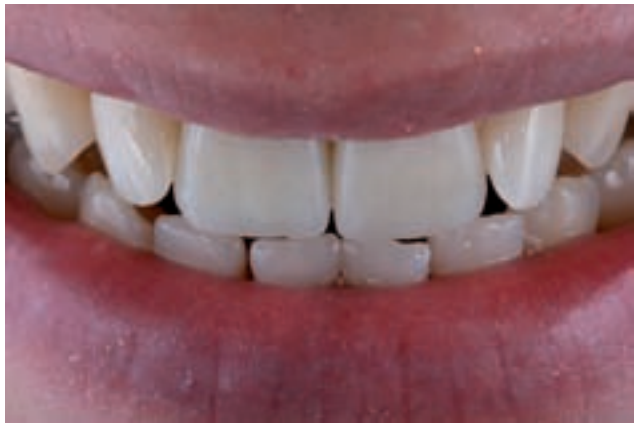


Fig. 11.54 The final result, showing the patient's smile.

Conclusions

For every implant-supported restoration the final objective is a long-lasting result providing function and esthetics. However, problems and complications may occur as with any biologic procedure. A complication in an esthetic area should be evaluated in the same manner as was done with the initial treatment planning. The clinician should use an esthetic checklist to see whether it is possible to correct the issue, considering the biology of the problem and the technology available.

Take-home hints

- *Treatment planning*: Digital photography is essential to help develop all the steps of the treatment. "Our own pictures are our own best teacher" (53). Always give the patient more than one option based on his or her desires and expectations and the biologic conditions that are present. Describe the entire treatment sequence to the patient, explaining biologic limitations. Make sure the patient understands the above and signs an informed consent.
- *Communication with the dental laboratory and the ceramist*: Contact the dental lab technician and the ceramist as part of the team before deciding on the final treatment planning and sequence. If possible, introduce the ceramist to the patient.
- *Temporary restorative phase*: Try to customize the provisional to act as a blueprint for the final esthetic restoration. Then only proceed with the final restoration if the patient is comfortable and happy with the provisional restoration. If not, make another provisional, and again discuss the expectations and limitations of the restoration.
- *Time of the treatment*: Have patience; never conclude the case before biology has done its job. The clinician and patient should decide when the treatment is concluded. The patient should achieve a satisfactory result. However, an experienced clinician should know when all reasonable and proper procedures have been made available.
- *Follow a checklist before and during all phases of treatment*: Follow the planning, implant placement, provisionalization, and final restoration to avoid and treat complications.
- *Clinical control*: At the first follow-up appointment after conclusion of treatment re-examine the implant and restoration before the dental hygienist begins the maintenance.

Acknowledgments

The authors would like to express their gratitude and are indebted to Dr Ariovaldo Stefani, Dr Mauricio Adolfi, Dr Robert Carvalho Silva, and Dr Sergio Siqueira Jr, for help, support, and providing some clinical cases and pictures; also the dental technicians/ceramists Luiz Alves Ferreira, Marcos Celestrino, and José Carlos Romanini, for technical and laboratory work, and Dr Andre Reis for grammar and spelling review.

References

1. van Steenberghe D, Lekholm U, Bolender C, Folmer T, Henry P, Herrmann I, *et al*. Applicability of osseointegrated oral implants in the rehabilitation of partial edentulism: a prospective multicenter study on 558 fixtures. *Int J Oral Maxillofac Implants* 1990; **5**: 272–81.
2. Astrand P. Engquist B, Anzén B, Bergendal T, Hallman M, Karlsson U, *et al*. A three-year follow-up report of a comparative study of ITI dental implants and Brånemark system implants in the treatment of the partially edentulous maxilla. *Clin Oral Implants Res* 2004; **6**: 130–41.
3. Lekholm U, Gröndahl K, Jemt T. Outcome of oral implant treatment in partially edentulous jaws followed 20 years in clinical function. *Clin Implant Dent Related Res* 2006; **8**: 178–86.
4. Belser UC, Schmid B, Higginbottom F, Buser D. Outcome analysis of implant restorations located in the anterior maxilla: a review of the recent literature. *Int J Oral Maxillofac Implants* 2004; **19** (Suppl): 30–42.
5. Bashutski JD, Wang HL. Common implant esthetic complications. *Implant Dent* 2007; **16**: 340–8.
6. Gervais MJ, Wilson PR. A rationale for retrievability of fixed, implant-supported prostheses: a complication-based analysis. *Int J Prosthodont* 2007; **20**: 13–24.
7. Meijer HJ, Stellingsma K, Meijndert L, Raghoebar GM. A new index for rating aesthetics of implant-supported single crowns and adjacent soft tissues – the Implant Crown Aesthetic Index. *Clin Oral Implants Res* 2005; **16**: 645–9.
8. Fürhauser R, Florescu D, Benesch T, Haas R, Mailath G, Watzek G. Evaluation of soft tissue around single-tooth implant crowns: the pink esthetic score. *Clin Oral Implants Res* 2005; **16**: 639–44.
9. Gehrke P, Lobert M, Dhom G. Reproducibility of the pink esthetic score – rating soft tissue esthetics around single-implant restorations with regard to dental observer specialization. *J Esthet Restor Dent* 2008; **20**: 375–84.
10. Andersson L, Emami-Kristiansen Z, Högström J. Single-tooth implant treatment in the anterior region of the maxilla for treatment of tooth loss after trauma: a retrospective clinical and interview study. *Dent Traumatol* 2003; **19**: 126–31.
11. Zetu L, Wang HL. Management of interdental/interimplant papilla. *J Clin Periodontol* 2005; **32**: 831–9.
12. Tarnow DP, Magner AW, Fletcher P. The effect of the distance from the contact point to the crest of bone on the presence or absence of the interproximal dental papilla. *J Periodontol* 1992; **63**: 995–6.
13. Salama H, Salama M. The role of orthodontic extrusive remodeling in the enhancement of soft and hard tissue profiles prior to implant placement: a systematic approach to the management of extraction site defects. *Int J Periodont Restor Dent* 1993; **13**: 312–33.
14. Salama H, Salama M, Kelly J. The orthodontic–periodontal connection in implant site development. *Pract Periodont Aesthet Dent* 1996; **8**: 923–32.
15. Araújo M, Linder E, Lindhe J. The influence of Bio-Oss collagen on healing of an extraction socket: an experimental study in the dog. *Int J Periodont Restor Dent* 2008; **28**: 123–35.
16. Araújo M, Linder E, Wennström J, Lindhe J. Effect of a xenograft on early bone formation in extraction sockets: an experimental study in dog. *Clin Oral Implants Res* 2009; **20**: 1–6.
17. Fickl S, Zuhr O, Wachtel H, Bolz W, Huerzeler MB. Hard tissue alterations after socket preservation: an experimental study in the beagle dog. *Clin Oral Implants Res* 2008; **19**: 111–18.
18. Grunder U, Gracis S, Capelli M. Influence of the 3-D bone-to-implant relationship on esthetics. *Int J Periodont Restor Dent* 2005; **25**: 113–19.
19. Saadoun AP, LeGall M, Touati B. Selection and ideal tridimensional implant position for soft tissue aesthetics. *Pract Periodont Aesthet Dent* 1999; **11**: 1063–72.
20. Salama M, Salama H, Garber DA. Guidelines for aesthetic restorative options and implant site enhancement: the utilization of orthodontic extrusion. *Pract Proced Aesthet Dent* 2002; **14**: 125–30.
21. Santoro V, De Donno A, Dell'Erba A, Introna F. Esthetics and implantology: medico-legal aspects. *Minerva Stomatol* 2007; **56**: 45–51.
22. Spear FM, Kokich VG. A multidisciplinary approach to esthetic dentistry. *Dent Clin N Am* 2007; **51**: 487–505, x–xi.
23. Funato A, Salama MA, Ishikawa T, Garber DA, Salama H. Timing, positioning, and sequential staging in esthetic implant therapy: a four-dimensional perspective. *Int J Periodont Restor Dent* 2007; **27**: 313–23.
24. Schropp L, Isidor F. Timing of implant placement relative to tooth extraction. *J Oral Rehabil* 2008; **35** (Suppl 1): 33–43.
25. Coachman C, Salama M, Garber D, Calamita M, Salama H, Cabral G. Prosthetic gingival reconstruction in the fixed partial restoration – Part 1: Introduction to artificial gingiva as an alternative therapy. *Int J Periodont Restor Dent* 2009; 29: 471–7.
26. Kan JY, Rungcharassaeng K, Umezu K, Kois JC. Dimensions of peri-implant mucosa: an evaluation of maxillary anterior single implants in humans. *J Periodontol* 2003; **74**: 557–62.
27. Davarpanah M, Martinez H, Celletti R, Tecucianu JF. Three-stage approach to aesthetic implant restoration: emergence profile concept. *Pract Proced Aesthet Dent* 2001; **13**: 761–7.
28. Kois JC, Kan JY. Predictable peri-implant gingival aesthetics: surgical and prosthodontic rationales. *Pract Proced Aesthet Dent* 2001; **13**: 691–8.

29. Bianchi AE, Sanfilippo F. Single-tooth replacement by immediate implant and connective tissue graft: a 1–9-year clinical evaluation. *Clin Oral Implants Res* 2004; **15**: 269–77.
30. Burkhardt R, Joss A, Lang NP. Soft tissue dehiscence coverage around endosseous implants: a prospective cohort study. *Clin Oral Implants Res* 2008; **19**: 451–7.
31. Mitrani R, Adolfi D, Tacher S. Adjacent implant-supported restorations in the esthetic zone: understanding the biology. *J Esthet Restor Dent* 2005; **17**: 211–22.
32. Adell R, Eriksson B, Lekholm U, Brånemark PI, Jemt T. Long-term follow-up study of osseointegrated implants in the treatment of totally edentulous jaws. *Int J Oral Maxillofac Implants* 1990; **5**: 347–59.
33. Buser D, Martin W, Belser UC. Optimizing esthetics for implant restorations in the anterior maxilla: anatomic and surgical considerations. *Int J Oral Maxillofac Implants* 2004; **19** (Suppl): 43–61.
34. Abrahamsson I, Berglundh T, Lindhe J. The mucosal barrier following abutment dis/reconnection. An experimental study in dogs. *J Clin Periodontol* 1997; **24**: 568–72.
35. Abrahamsson I, Berglundh T, Sekino S, Lindhe J. Tissue reactions to abutment shift: an experimental study in dogs. *Clin Implant Dent Related Res* 2003; **5**: 82–8.
36. Small PN, Tarnow DP, Cho SC. Gingival recession around wide-diameter versus standard-diameter implants: a 3- to 5-year longitudinal prospective study. *Pract Proced Aesthet Dent* 2001; **13**: 143–6.
37. Berglundh T, Lindhe J, Marinello C, Ericsson I, Liljenberg B. Soft tissue reaction to *de novo* plaque formation on implants and teeth. An experimental study in the dog. *Clin Oral Implants Res* 1992; **3**: 1–8.
38. Goodacre CJ, Bernal G, Rungcharassaeng K, Kan KY. Clinical complications with implants and implant prostheses. *J Prosthet Dent* 2003; **90**: 121–32.
39. Brägger U, Aeschlimann S, Bürgin W, Hämmerle CH, Lang NP. Biological and technical complications and failures with fixed partial dentures (FPD) on implants and teeth after four to five years of function. *Clin Oral Implants Res* 2001; **12**: 26–34.
40. Malament KA. Prosthodontics: achieving quality esthetic dentistry and integrated comprehensive care. *J Am Dent Assoc* 2000; **131**: 1742–9.
41. Fradeani M, Barducci G. *Esthetic analysis: a systematic approach to prosthetic treatment*, 1st edn, Vol. 1. Chicago, IL: Quintessence, 2004: 137–243.
42. Nedir R, Bischof M, Szmukler-Moncler S, Belser UC, Samson J. Prosthetic complications with dental implants: from an up-to-8-year experience in private practice. *Int J Oral Maxillofac Implants* 2006; **21**: 919–28.
43. Adolfi D. Functional, esthetic, and morphologic adjustment procedures for anterior teeth. *Quintessence Dent Technol* 2009; **32**: 153–68.
44. Tjan AH, Miller GD, The JG. Some esthetic factors in a smile. *J Prosthet Dent* 1984; **51**: 24–8.
45. Tarnow DP, Cho SC, Wallace SS. The effect of inter-implant distance on the height of inter-implant bone crest. *J Periodontol* 2000; **71**: 546–9.
46. Tarnow DP, Elian N, Fletcher P, Froum S, Magner A, Cho SC, *et al*. Vertical distance from the crest of bone to the height of the interproximal papilla between adjacent implants. *J Periodontol* 2003; **74**: 1785–8.
47. Choquet V, Hermans M, Adriaenssens P, Daelemans P, Tarnow DP, Malevez C. Clinical and radiographic evaluation of the papilla level adjacent to single-tooth dental implants. A retrospective study in the maxillary anterior region. *J Periodontol* 2001; **72**: 1364–71.
48. Kan JY, Rungcharassaeng K. Interimplant papilla preservation in the esthetic zone: a report of six consecutive cases. *Int J Periodont Restor Dent* 2003; **23**: 249–59.
49. Elian N, Ehrlich B, Jalbout ZN, Classi AJ, Cho SC, Kamer AR, *et al.* Advanced concepts in implant dentistry: creating the "aesthetic site foundation". *Dent Clin N Am* 2007; **51**: 547–63.
50. Kois JC. The restorative–periodontal interface: biological parameters. *Periodontol 2000* 1996; **11**: 29–38.
51. Kois JC. Predictable single tooth peri-implant esthetics: five diagnostic keys. *Compend Contin Educ Dent* 2001; **22**: 199–206.
52. Park SE, Da Silva JD, Weber HP, Ishikawa-Nagai S. Optical phenomenon of peri-implant soft tissue. Part I. Spectrophotometric assessment of natural tooth gingiva and peri-implant mucosa. *Clin Oral Implants Res* 2007; **18**: 569–74.
53. Edelhoff D. Entrevista: Daniel Edelhoff. *Revista Dental Press Estética* 2008; **5**: 20–6 [in Portuguese].

Chapter 12

Esthetic complications with adjacent implant restorations

Dennis P. Tarnow DDS, *Sang-Choon Cho* DDS, *and Stuart J. Froum* DDS

Complications

The most common complication that arises from placing two adjacent implants in the esthetic zone is the loss of the height of the interdental papilla. This problem will often result in patient dissatisfaction with the final restorative outcome even when implant integration is successful, and crown color size and contour are ideal. A deficient papilla leads to the classic "black triangle" that forms interproximally between two adjacent teeth or implant crowns (Fig. 12.1) (1). This generates an auxiliary complication when the restorative dentist attempts to mask this dark space with overcontoured restorations or pink ceramics (Fig. 12.2) (2). Both of these restorative solutions are often considered a poor compromise by both the patient and the dentist.

The average height of interproximal tissue from the interimplant bone peak to the height of the papilla has been reported to be approximately 3.5 mm (3). This is 2 mm shorter than the average papilla height normally seen between two adjacent teeth (1, 4). This difference becomes a major complication for a patient with a high smile line and when there is asymmetric tooth loss. For example, if a maxillary central and the adjacent lateral incisor are being replaced with implants and the contralateral side of the mouth has healthy full papillae between the teeth, the overall esthetic appearance will be compromised by the asymmetry (Fig. 12.3) (5). The only area where a shorter papilla is not a major concern is between the maxillary central incisors. This is because the difference in papillae height between the central incisors and central and lateral incisor is not noticeable to the eye since the shorter papilla is directly in the center of the patient's smile. The clinician creates a slightly broader, more apical crown contact area and the result is usually acceptable (6).

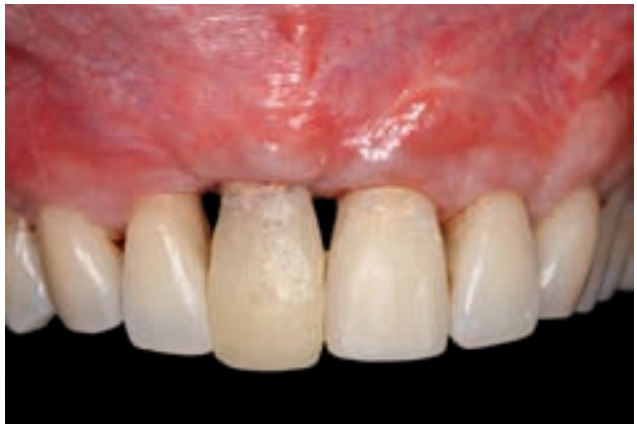


Fig. 12.1 Deficient interproximal papilla between a right central incisor implant and the adjacent tooth leading to the "black triangle".

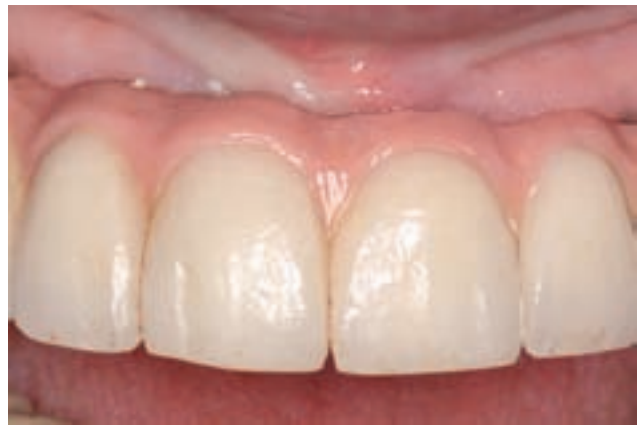


Fig. 12.2 Pink ceramics used to close the interproximal spaces when papillae are deficient.

Etiology

The etiology of the loss of the interproximal tissue is related to multiple problems along the treatment path. The most common cause involves the loss of the interdental bone. This can take place from previous periodontal or endodontic disease on the teeth that were extracted or from excessive trauma during the removal of the teeth. The reflection of a flap during extraction can cause increased bone loss of the buccal plate and the interdental papillae (7). This is especially true if the interdental papillae are included as part of the flap reflection when the implants are placed. In fact, there is a greater risk of

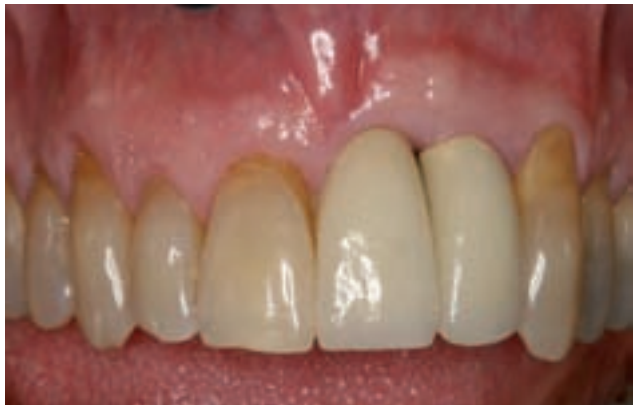


Fig. 12.3 An unesthetic result with two adjacent implant restorations on the maxillary left central and lateral incisors. The papillae are significantly more apical than those between the contralateral natural teeth.

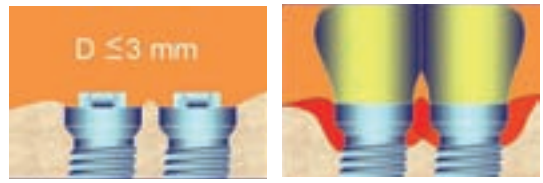


Fig. 12.5 Implants with standard abutments placed closer than 3 mm apical will result in an overlap of biologic width resorption with loss of interproximal bone and soft tissue.

Fig. 12.6 Interproximal distance >3 mm may still present a deficient papilla height because of the average height of papillae between two implants.

increased bone loss with reflection of the papillae than when papilla-saving incisions are used (Fig. 12.4) (8). The placement of the implants too close to one another is another cause of interimplant bone loss. When an abutment is placed on an implant with an equal or smaller sized diameter, the bone level will resorb apically by approximately 1.5–2.0 mm from the abutment–implant connection (9–12). However, as the bone resorbs apically along the implant, it resorbs laterally as well. The bone loss is therefore three-dimensional. The horizontal bone resorption has been documented to average approximately 1.4 mm. When implants are placed closer than 3 mm apart increased crestal bone loss between the two implants has been reported to occur (Fig. 12.5) (9). However, placement of the implants at least 3 mm apart may still not prevent the loss of papilla height. Often the interimplant bone level is normal but the papilla is still deficient in height (Fig. 12.6). This again is the result of the 3.5 mm average height of the papillae when the bone to interproximal contact point is generally 4.5–5.0 mm.

The major significance in losing the interimplant bone, and the reason that two adjacent implants are so problematic from an esthetic point of view, is that loss of the supracrestal soft-tissue attachment accompanies the bone loss. If an implant is adjacent to a periodontally healthy tooth, the papilla is usually normal in appearance and height (13, 14). The reason for this is that the papilla is supported by the gingival fibers and the epithelial attachment of the adjacent tooth. In these cases the biologic width of tissue is supracrestal in position (Fig. 12.7), which gives physical support and blood supply to the papilla. When two implants are adjacent to each other the biologic width is subcrestal. This biologic variance is one reason why the papilla is shorter when implants are placed adjacent to each other in the esthetic zone. An additional etiologic factor is related to the detachment of the epithelial tissue adhering to the abutment each time the abutment is changed before final placement. This causes the epithelial tissues (which

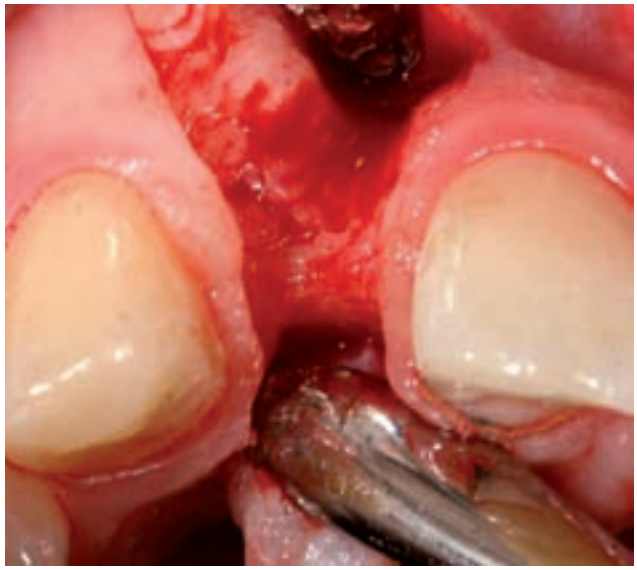


Fig. 12.4 Incisions which preserve the papillae on teeth adjacent to the implant serve to preserve interproximal bone.

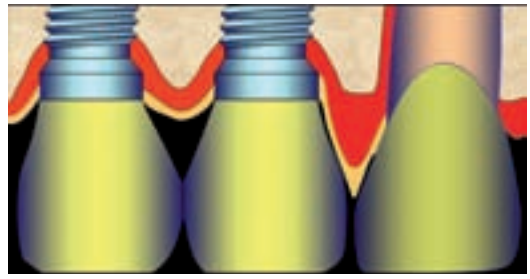


Fig. 12.7 The papilla between a natural tooth and an implant is supported by gingival fibers and bone on the buccal aspect of the tooth.

initially may be supracrestal) to move apically, resulting in the loss of support for the papillae (15).

Prevention

Treatment planning for two adjacent implants in the esthetic zone must begin before extraction of the hopeless teeth. If there is recession or bone loss around one or both of the teeth planned for extraction, orthodontic forced eruption before tooth extraction is often helpful in moving the soft- and hard-tissue complex coronally (16). Atraumatic extraction without flap and papilla reflection is an effective method of conserving hard and soft tissue. Socket preservation using bone grafts, bone graft substitutes, and membranes is another way to conserve the morphology of the socket and papillae (17). Lastly, soft- and hard-tissue augmentation of a deficient edentulous ridge in the esthetic zone may serve to rebuild hard and soft tissue before implant placement. All of these procedures may help to avoid the necessity of constructing two adjacent implant crowns that are extremely long, apicocoronally, in comparison to those of the normal surrounding teeth.

At present, the most reliable method of preventing this papilla problem is to avoid the placement of two implants adjacent to each other in the esthetic zone, except in the central incisor areas. In addition, papilla-saving incisions should be used whenever possible to decrease bone loss interproximally (8). The placement of adjacent implants in central incisor–lateral incisor or lateral incisor–cuspid areas on one side of the mouth, when there are normal healthy papillae and teeth on the contralateral side, in most cases, will result in an esthetic failure (Fig. 12.8). An alternative option is to cantilever an ovate pontic from the central incisor or cuspid implant restoration (Fig. 12.9) (6). When a hard- or soft-tissue defect is present, augmentation of the edentulous ridge with soft tissue or bone grafts is often necessary before placing an ovate pontic in the edentulous lateral incisor area. In addition, the occlusion should be adjusted to avoid pressure on the cantilevered tooth in centric occlusion as well as in excursive movements. This has been recommended as an excellent method of preventing the esthetic problem caused by a deficient papilla (18, 19). If the four maxillary incisors are missing, placement of two non-adjacent implants in the lateral incisor areas with two central incisor pontics, or in the lateral incisor and the contralateral central incisor areas replacement of the two other missing teeth with ovate pontics, will yield a favorable esthetic result (Fig. 12.10).

Other methods to prevent this papilla problem from occurring are still experimental and need more research. Some techniques appear encouraging; however, there is little or no research to prove their predictability and long-term success. Several strategies that show promise in allowing placement of adjacent implants incorporate one or more techniques. These techniques include using a one-piece implant (20), placing the final abutment at the time of surgery and not removing it (21), using a scalloped platform implant (22), removing the abutment only once instead of multiple times (23), and platform switching (24, 25). The last technique incorporates the use of a smaller diameter abutment on an implant with a

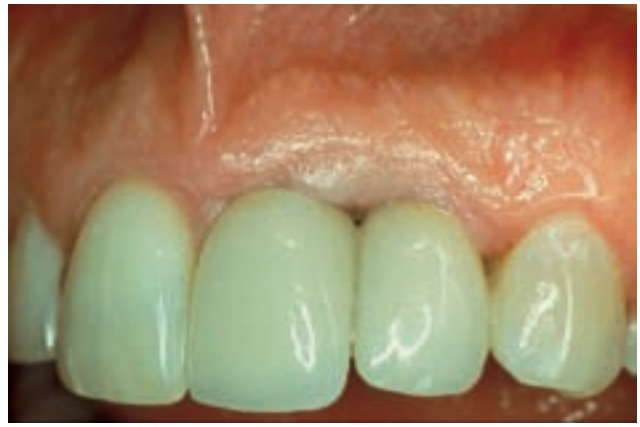


Fig. 12.8 Two adjacent implants in the left central and lateral areas pose an esthetic complication where the papilla is shorter than those around the adjacent teeth, resulting in an esthetic failure.

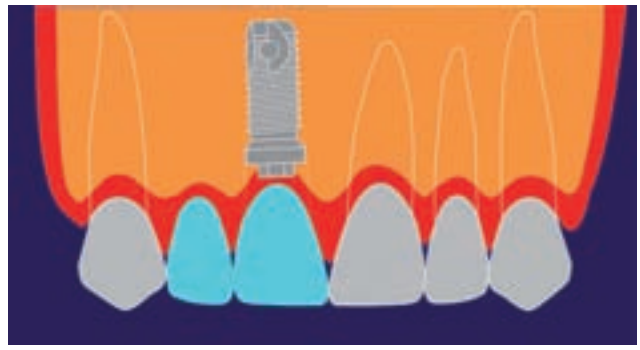


Fig. 12.9 When two adjacent teeth are missing in the esthetic zone, placement of an implant and a cantilevered pontic can produce an excellent esthetic result with the appearance of papillae of normal height.

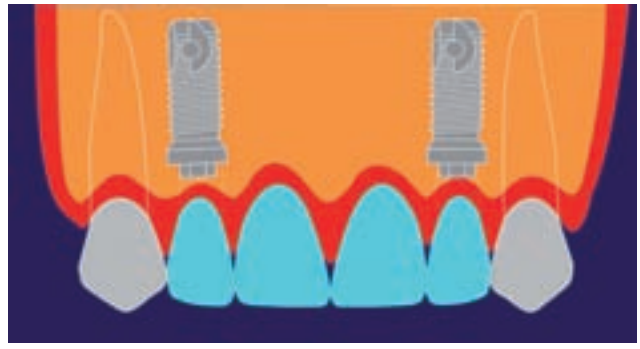


Fig. 12.10 When the four maxillary incisors are missing, placement of two non-adjacent implants will yield an esthetically successful result.

larger diameter platform. These have all been used with different degrees of success (25). However, more research and long-term data are needed to determine which, if any, may be practical. Until such time, the best option for prevention of the esthetic problem experienced with two adjacent implants remains using one implant with a cantilevered ovate pontic, as mentioned earlier.

Treatment

If the complication of a deficient papilla occurs there are several treatment options that may be useful. The one most frequently used involves a restorative solution. This can be accomplished by making the crowns a little wider and by elongating the crown contact points. As discussed earlier, this can be successful with two adjacent central incisor implants (Fig. 12.11a, b). This, however, may distort the appearance of the final restoration and the patient may not be satisfied. Another method combines crown lengthening of the teeth adjacent to the two implants and then restoring all of the teeth in the esthetic zone in an attempt to obtain a symmetric esthetic result. This, while improving an overtly unesthetic result, is not optimum to the discerning eye and the patient with high esthetic demands (Fig. 12.12a–d). A third method is to close the embrasure space using pink porcelain ceramic (Fig. 12.13). This treatment has the benefit of maintaining the normal tooth shape while eliminating the dark triangle. This can be successful. However, it requires a talented ceramist to match the color of the patient's tissues. Moreover, although the pink ceramics have been improved, they are still far from ideal in many cases.

If pink ceramics or composites do not correct the esthetic problem, a surgical alternative may be required to submerge permanently one of the implants (preferably the lateral incisor) using a thick connective tissue graft (Figs 12.14 and 12.15). Then, after 2 months, a small ovate pontic can be placed over this area. Another surgical alternative is to remove one of the implants completely. However, this may cause a large ridge defect which may be difficult to correct and may require multiple hard- and soft-tissue surgeries. Therefore, it is usually preferable to submerge one implant to retain the ridge anatomy and simplify the correction.

Some clinicians have attempted repair of a deficient papilla by means of surgical correction. This has been described in case reports only (26, 27). Unfortunately, at this time, there is no surgical repair technique that has been shown to be reliable. The difficulty of achieving reliable surgical repair of the deficient papilla involves the limited blood supply in this area. The vascularity is further compromised when the papilla is reflected and advanced in order to cover and submerge the graft tissue or material. The few case reports that have been published are of areas that have a large mesial–distal space between the adjacent teeth (28). This allows the clinician an increased chance of success since a wider space presents a better blood supply. However, many papilla problems have become worse after attempts at papilla reconstruction, owing to further compromise of the blood supply to this tissue. Therefore, this treatment should be avoided if possible, except by expert clinicians in very select cases. An example of the complexity of treating this problem can be seen in the following case. (All prosthetic treatment in this case was performed by Dr Chu.)

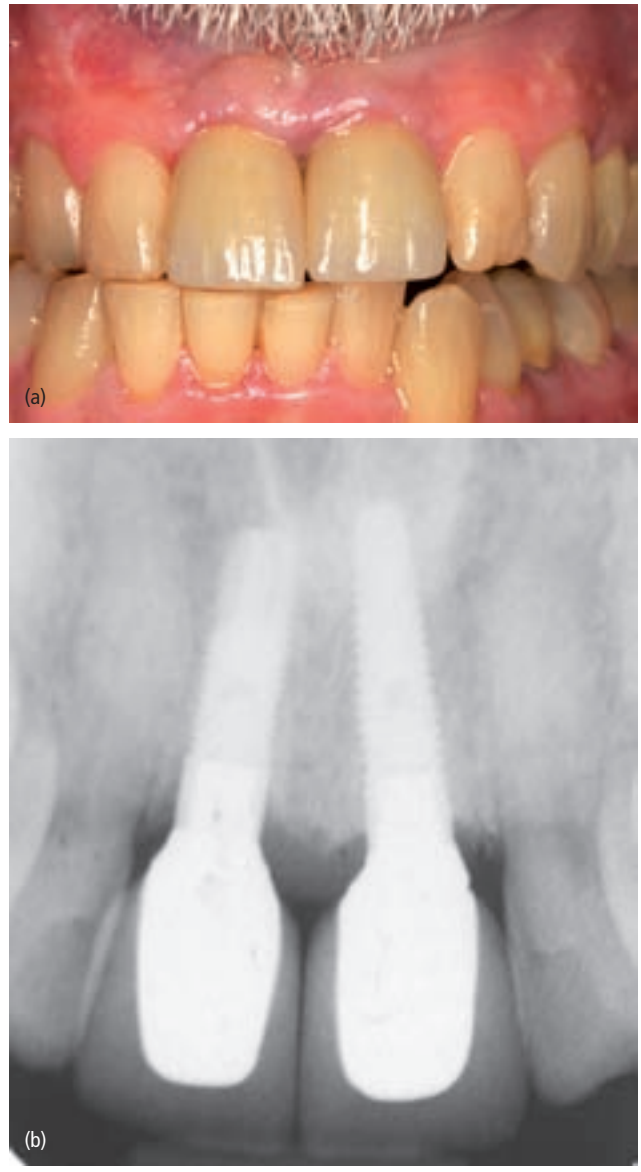
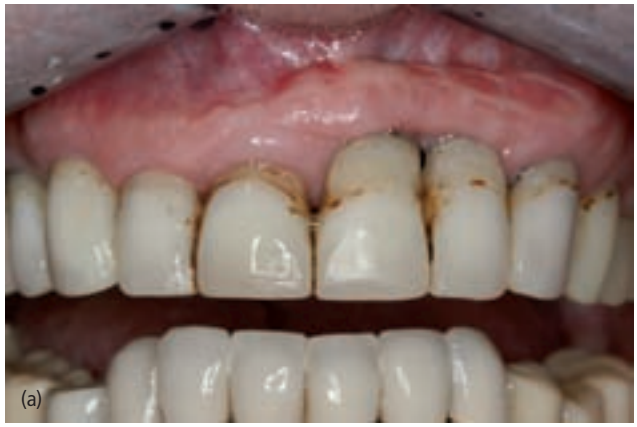
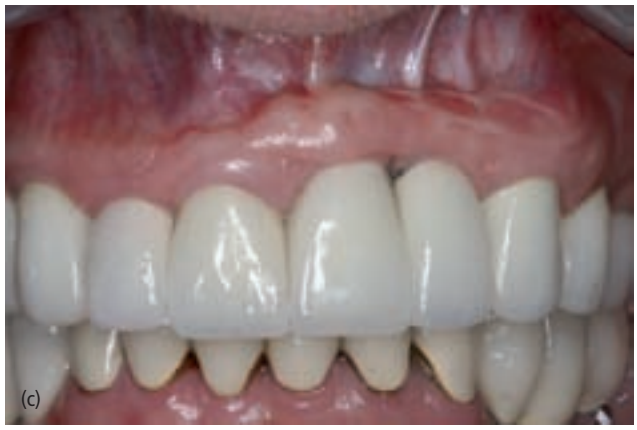
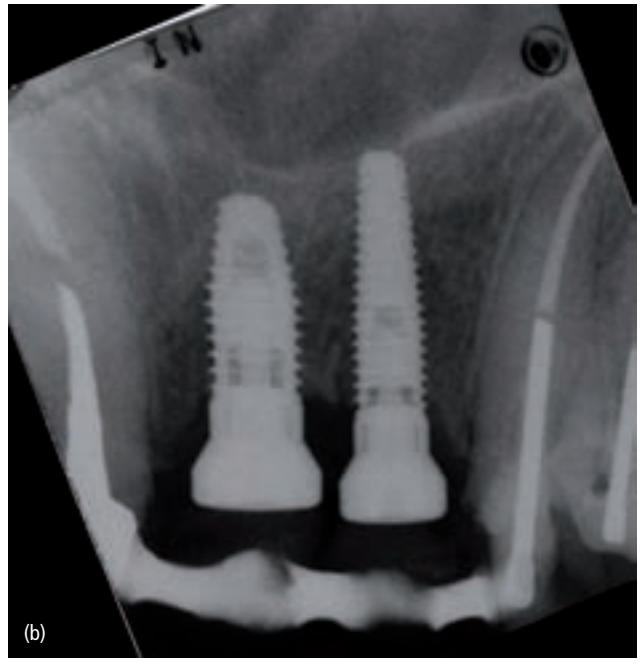


Fig. 12.11 (a, b) Elongating the contact point between two central incisor implant-supported crowns will produce an acceptable esthetic result since there is an asymmetric appearance of the maxillary anterior teeth.







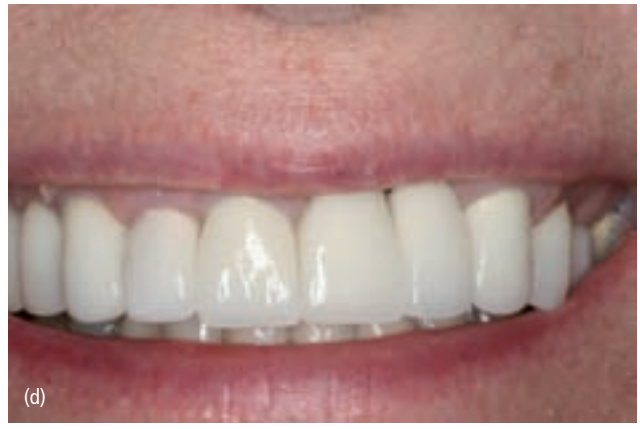


Fig. 12.12 (a–d) Crown lengthening of the teeth adjacent to the two implants and then restoration of all the teeth in the esthetic zone in an attempt to obtain a symmetric esthetic result. This, although improving an overtly unesthetic result, is not optimum to the discerning eye and the patient with high esthetic demands.

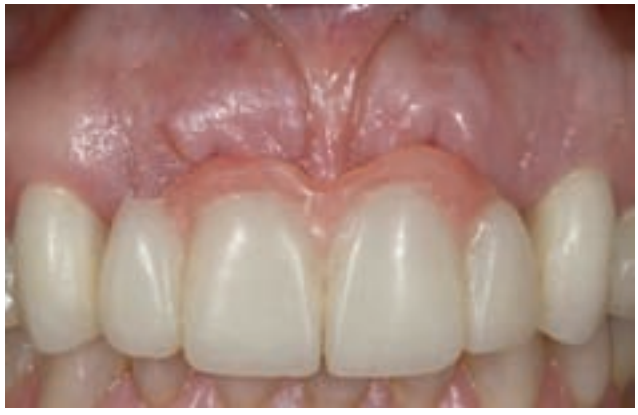


Fig. 12.13 Another method of closing the interproximal space uses pink ceramics to mimic the soft tissue.

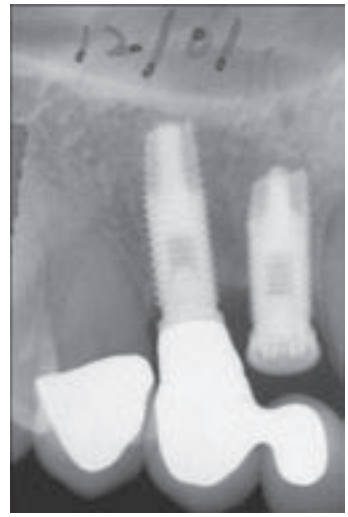


Fig. 12.14 As observed on this radiograph, when two asymmetric implants are placed (right central and lateral incisors), submerging one of the implants (lateral incisor) with a connective tissue graft creates the "cantilevered pontic" solution to preserving the interproximal papilla.

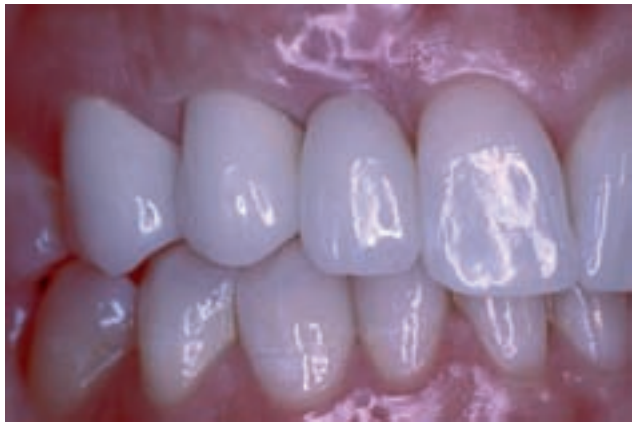


Fig. 12.15 The clinical result of submerging one implant presents the illusion of a papilla and a good esthetic result with the two adjacent implants seen in Fig. 12.14.

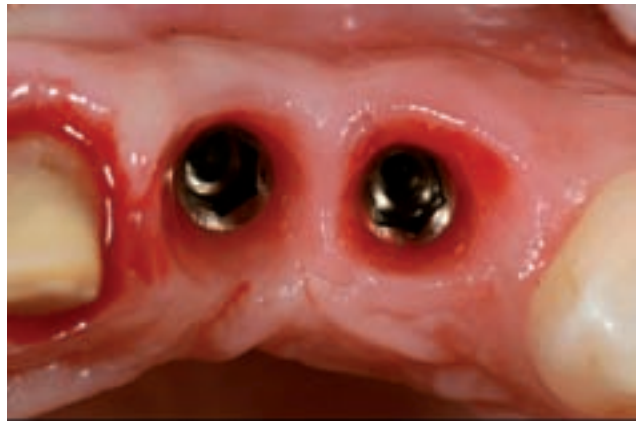


Fig. 12.17 Two adjacent implants in the esthetic zone with severe vertical bone defect.

The patient presented with a complaint of being unhappy with the esthetics in the area of the two adjacent implant-supported restorations in the maxillary left central and lateral incisors (Figs 12.16 and 12.17). There was a deficiency of the papilla between the two adjacent implants replacing these teeth, and the crowns and contact points were elongated to compensate for this (Fig. 12.16). A three-unit provisional was placed with two pontics (nos 9 and 10) cantilevered from the right central incisor (Fig. 12.18). The abutments were removed and replaced with cover screws which allowed the connective tissue and epithelium to partially cover the implants (Fig. 12.19a, b). The first surgery consisted of reflection of a full-thickness flap with papilla-preserving incisions on the mesial side of the right central incisor and left canine teeth (Fig. 12.20). A dermis allograft (Zimmer, Carlsbad, CA) was placed over the implant on the buccal and occlusal faces to augment the soft tissue (Fig. 12.21).

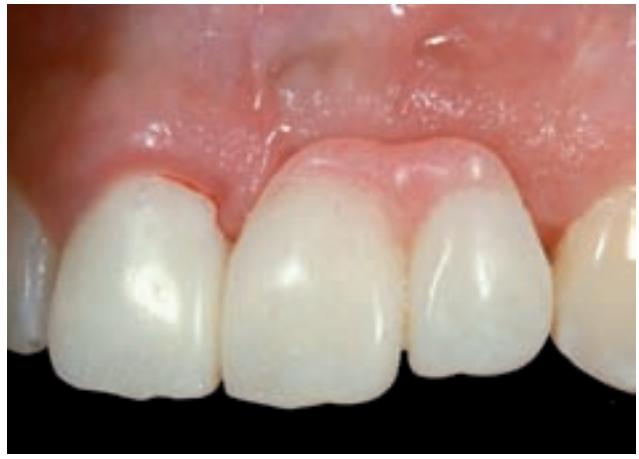


Fig. 12.18 Delivered provisional with pink acrylic.

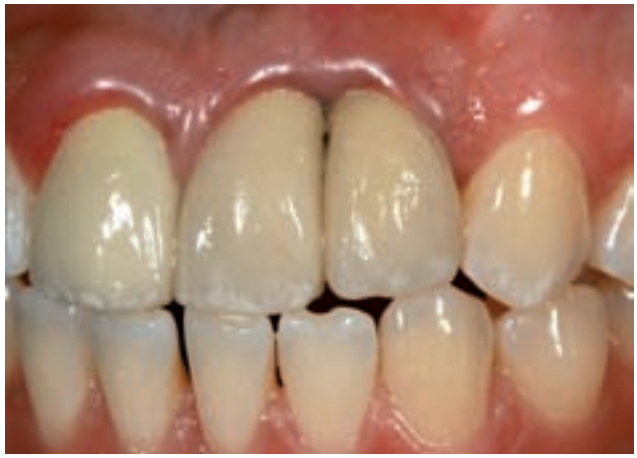
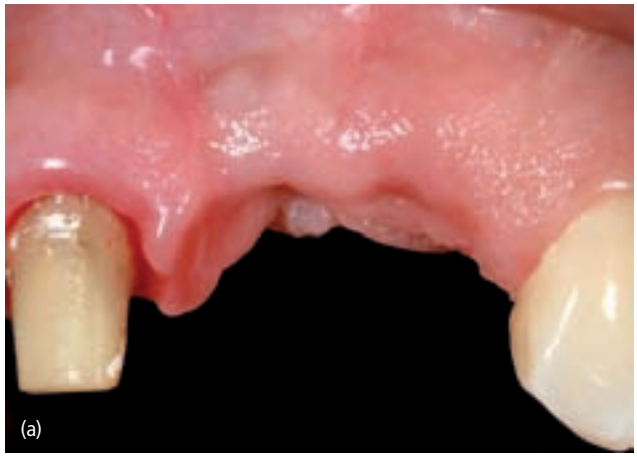


Fig. 12.16 Elongated contact point to close the embrasure space resulted in asymmetric and non-pleasing final restorations.

A subepithelial connective graft was placed on the occlusal aspect of the allograft (Fig. 12.22). Tension-free primary closure was achieved (Fig. 12.23). The provisional was replaced and contoured immediately. The healing went well around the reshaped provisional restoration (Fig. 12.24). Three months later, the area healed uneventfully (Fig. 12.25) and second surgery was performed with similar flap incisions and reflection (Fig. 12.26). A second dermis allograft was placed (Fig. 12.27) and the area again sutured without tension (Fig. 12.28). One week postsurgery, the area appeared to be healing well (Fig. 12.29). A third surgery, again using the dermis allograft, was performed and the graft was sutured to the palatal tissue for stabilization (Fig. 12.30). Three-and-a-half months posthealing, stage 2 surgery was performed (Fig. 12.31). The left central incisor implant was exposed (no. 9) and the lateral incisor (no. 10) left submerged "sleeping" (Fig. 12.32). The provisional three-unit restoration was cantilevered (no. 10) from implant numbers 8 and 9 (Fig. 12.33). Flat subgingival cervical



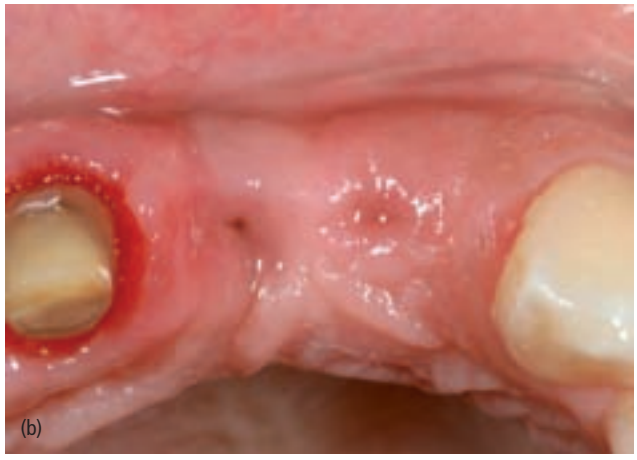


Fig. 12.19 (a, b) A cover screw was placed and the area allowed to heal for 3 weeks.

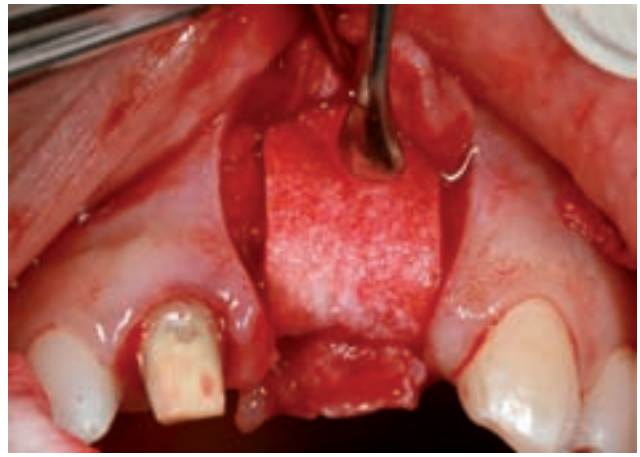


Fig. 12.21 A dermis allograft was used to increase tissue thickness.

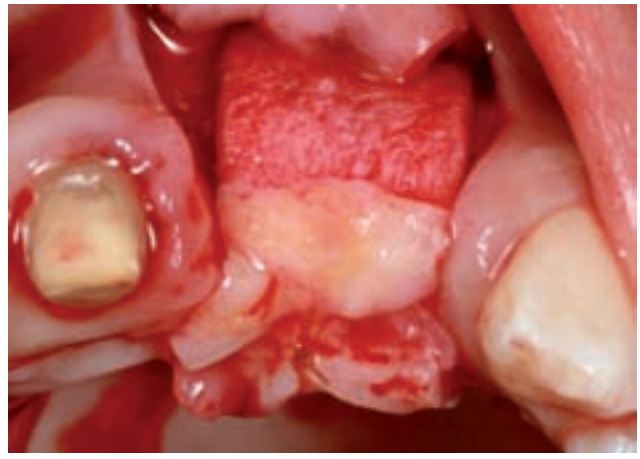


Fig. 12.22 Subepithelial graft occlusally to prevent dehiscence.

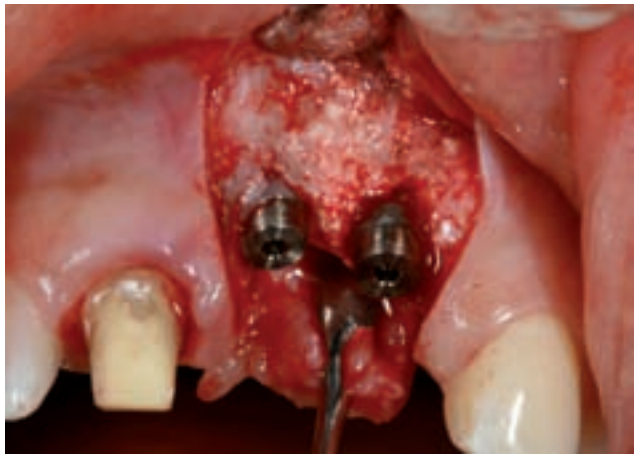


Fig. 12.20 First surgery, showing graft material from previous surgery.

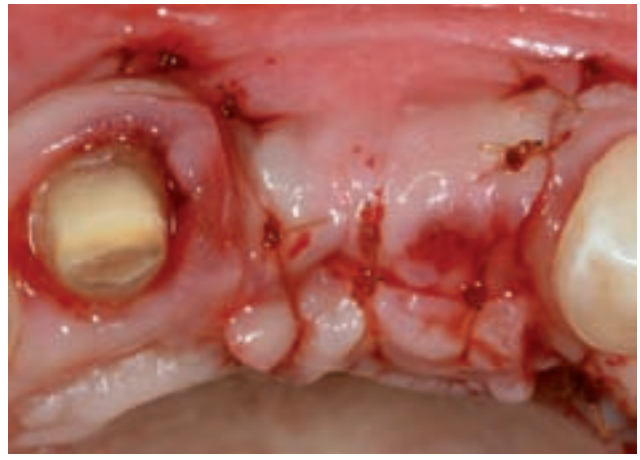


Fig. 12.23 Tension-free primary closure was achieved.

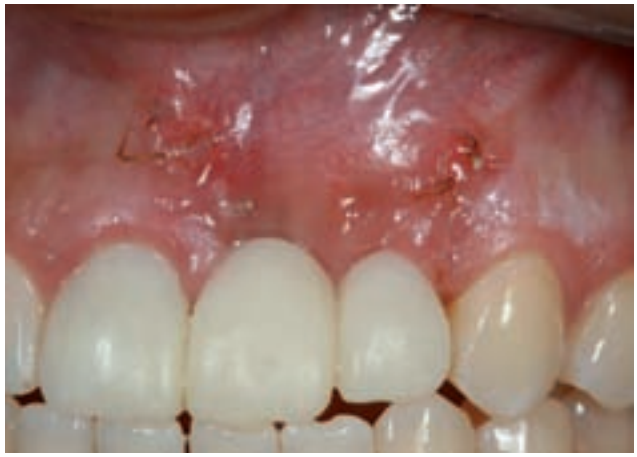


Fig. 12.24 One week after the operation.

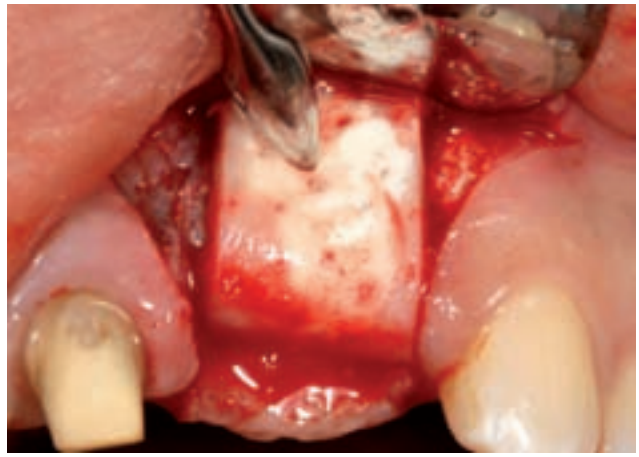


Fig. 12.27 Dermis allograft was used to increase tissue thickness.

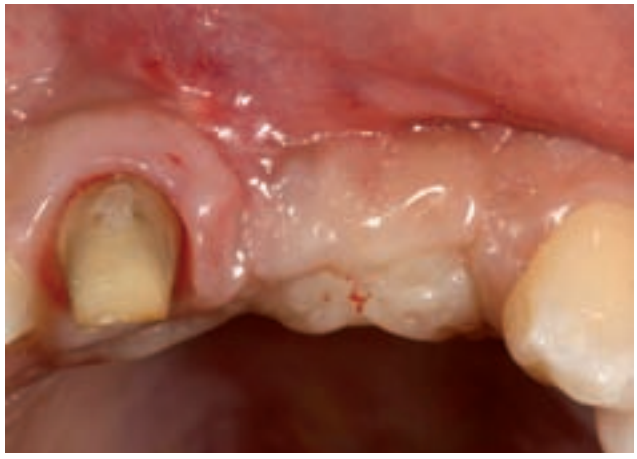


Fig. 12.25 Three months postoperative healing.

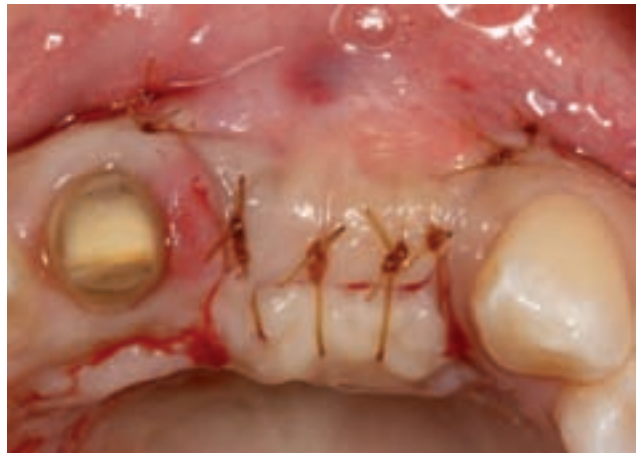


Fig. 12.28 Achieved tension-free primary closure.

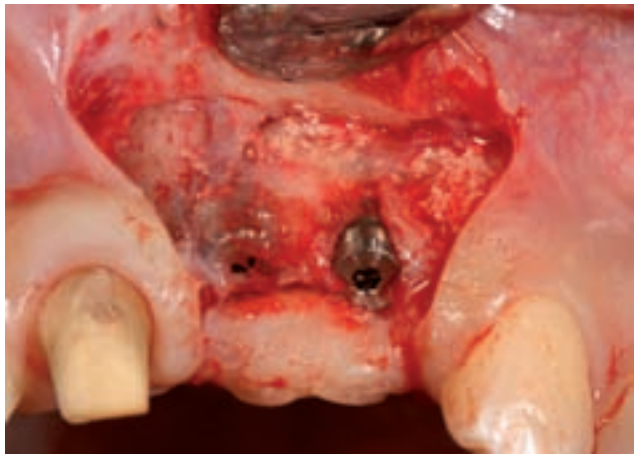


Fig. 12.26 Second surgery.

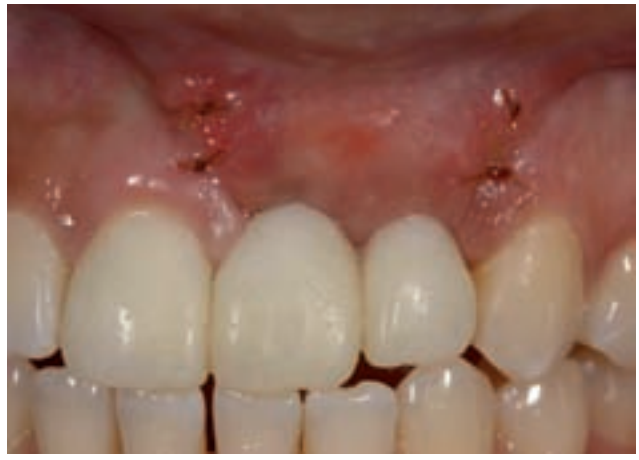


Fig. 12.29 One week postoperative healing.

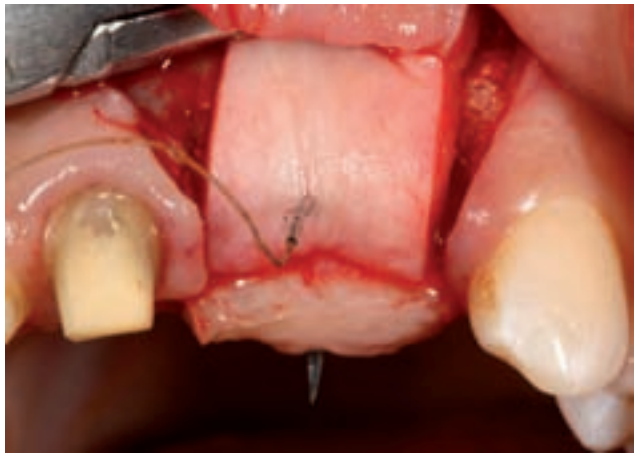


Fig. 12.30 Third surgery using a dermis allograft tissue matrix. The graft was sutured to palatal tissue for stabilization.

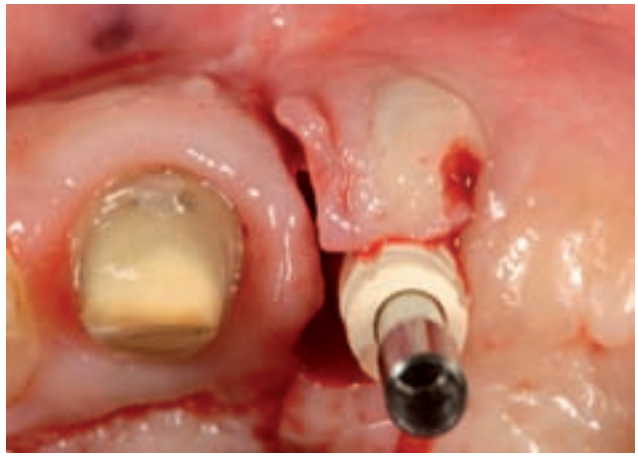


Fig. 12.33 Provisional restoration: no. 10 was cantilevered from nos 8 and 9.

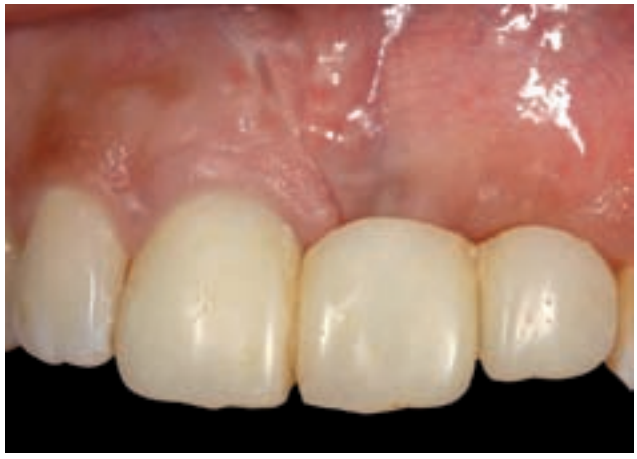


Fig. 12.31 Three-and-a-half months healing.

Fig. 12.34 Flat subgingival crown contours allowing coronal tissue migration.

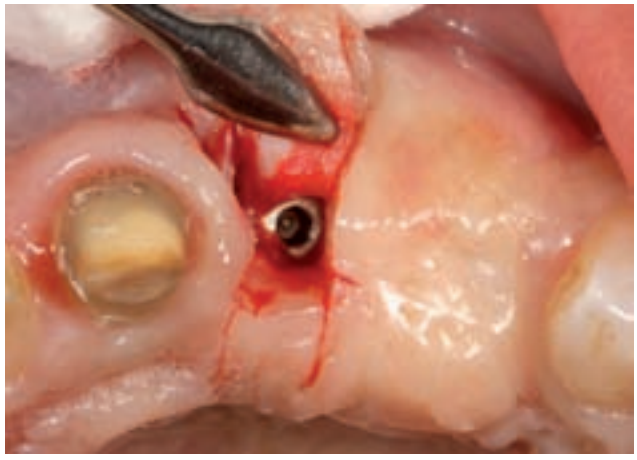


Fig. 12.32 Stage 2: uncovering surgery. Tooth 9 was exposed and implant no. 10 left submerged.

contours were created to allow the gingival tissue to migrate coronally (Fig. 12.34). The tissue is still healing but the interdental and buccal soft-tissue levels have been corrected (Fig. 12.35). The final restoration shows a significant esthetic improvement and the patient was very satisfied (Fig. 12.36). The final bridge was now in place with number 10 cantilevered off number 9. Compare Figs 12.16 and 12.36.

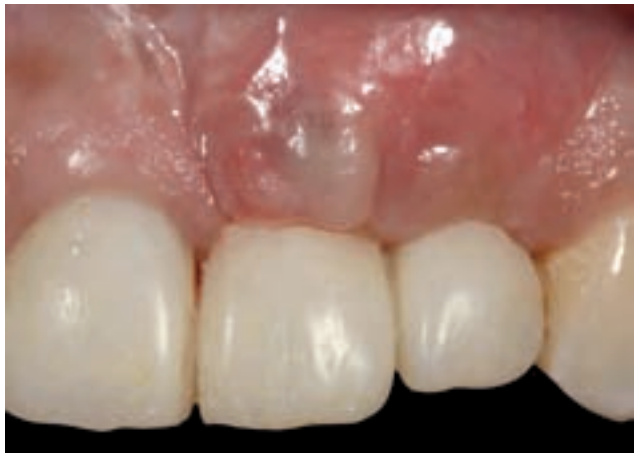


Fig. 12.35 Correction of interdental papilla height was achieved.

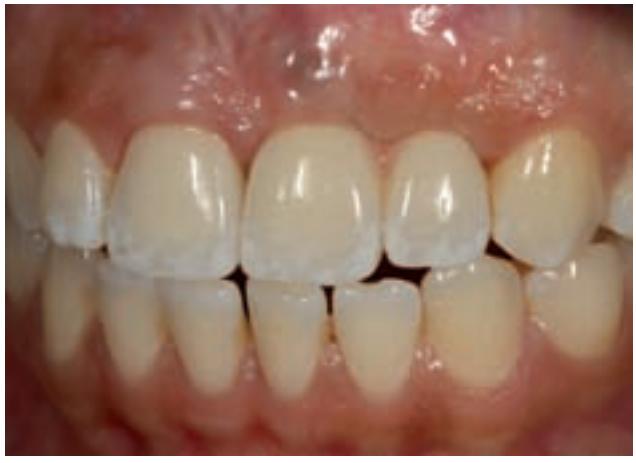


Fig. 12.36 Final restoration.

Conclusions

The complication of adjacent papillae arising from two adjacent implants in the esthetic zone is a serious one for both the patient and the clinician. This small piece of missing tissue is enough to make an otherwise successful case feel and look like a failure even though everything was performed well and followed biologic parameters. This is true even in the presence of healthy peri-implant tissue. This esthetic problem is one that is best prevented. This chapter has described the etiology, prevention, and treatment of this complication. Future research will hopefully make it more practical to place two adjacent implants in esthetically critical areas. Solutions may come from implants specifically designed for these situations as well as from the development of more reliable surgical techniques and materials for the clinician to use.

Take-home hints

- Before the extraction of two adjacent teeth in the esthetic zone consider orthodontic forced eruption, and then use an atraumatic extraction protocol avoiding flap reflection and disruption of interproximal papillae.
- Before delayed implant placement use guided bone regeneration procedures, block grafts and/or soft-tissue grafts to rebuild lost bone and soft tissue in the edentulous area.
- Place adjacent implants at least 3 mm apart to preserve interproximal bone.
- Where possible, avoid placement of two adjacent implants in asymmetric positions i.e. cuspid/lateral, central/lateral. Instead, use cantilevered ovate pontics to replace the lateral incisor and a single implant placed in either the central or cuspid area.

References

1. Tarnow DP, Magner AW, Fletcher P. The effect of the distance from the contact point to the crest of bone on the presence or absence of the interproximal dental papilla. *J Periodontol* 1992; **63**: 995–6.
2. Furhauser R, Florescu D, Benesch T, Haas R, Mailath G, Watzek G. Evaluation of soft tissue around single-tooth implant crowns: the pink esthetic score. *Clin Oral Implants Res* 2005; **16**: 639–44.
3. Tarnow D, Elian N, Fletcher P, Froum S, Magner A, Cho S-C, *et al*. The vertical distance from the crest of bone to the height of the interproximal papilla between adjacent implants. *J Periodontol* 2003; **74**: 1785–8.
4. Garber DA, Salama MA, Salama H. Immediate total tooth replacement. *Compend Contin Educ Dent* 2001; **22**: 210–18.
5. Carrick J, Petto LC, Ellison JT. Creating soft tissue symmetry around implants utilizing provisional restorations. *AACD* 2004; **1**: 49–52.
6. Spear FM, Kokich VG, Matthews DP. The esthetic management of a severe isolated periodontal defect in the maxillary anterior. *Compend Contin Educ Dent* 2008; **29**: 280–2, 284–7.
7. Cardaropoli G, Araujo M, Hayacibara R, Sukekava F, Lindhe J. Healing of extraction sockets and surgically produced – augmented and non-augmented – defects in the alveolar ridge. An experimental study in the dog. *J Clin Periodontol* 2005; **32**: 435–40.
8. Gomez-Roman G. Influence of flap design on peri-implant interproximal crestal bone loss around single-tooth implants. *Int J Oral Maxillofac Implants* 2001; **16**: 61–7.
9. Tarnow DP, Cho SC, Wallace SS. The effect of inter-implant distance on the height of the inter-implant bone crest. *J Periodontol* 2000; **71**: 546–9.

10. Hermann JS, Buser D, Schenk RK, Higginbottom FL, Cochran DL. Biologic width around titanium implants. A physiologically formed and stable dimension over time. *Clin Oral Implants Res* 2000; **11**: 1–11.
11. Hermann JS, Buser D, Schenk RK, Cochran DL. Crestal bone changes around titanium implants. A histometric evaluation of unloaded non-submerged and submerged implants in the canine mandible. *J Periodontol* 2000; **71**: 1412–24.
12. Hermann JS, Buser D, Schenk R, Schoolfield J, Cochran D. Biologic width around one- and two-piece titanium implants. A histometric evaluation of unloaded nonsubmerged and submerged implants in the canine mandible. *Clin Oral Implants Res* 2001; **12**: 559–71.
13. Grunder U. Stability of the mucosa; topography around single-tooth implants and adjacent teeth: 1-year results. *Int J Periodont Restor Dent* 2000; **20**: 11–17.
14. Choquet V, Hermans M, Adriaenssens P, Daelemans P, Tarnow D, Malevez C. Clinical and radiographic evaluation of the papilla level adjacent to single-tooth dental implants. A retrospective study in the maxillary anterior region. *J Periodontol* 2001; **72**: 1364–71.
15. Abrahamsson I, Cardaropoli G. Peri-implant hard and soft tissue integration to dental implants made of titanium and gold. *Clin Oral Implants Res* 2007; **18**: 269–74.
16. Salama H, Salama M. The role of orthodontic extrusive remodeling in the enhancement of soft and hard tissue profiles prior to implant placement: a systematic approach to the management of extraction site defects. *Int J Periodont Restor Dent* 1993; **13**: 312–33.
17. Araujo MG, Lindhe J. Dimensional ridge alterations following tooth extraction. An experimental study in the dog. *J Clin Periodontol* 2005; **32**: 212–18.
18. Salama H, Salama MA, Garber D, Adar P. The interproximal height of bone: a guidepost to predictable aesthetics strategies and soft tissue contours in anterior tooth replacement. *Pract Periodont Aesthet Dent* 1998; **10**: 1131–41.
19. Funato A, Salama MA, Ishikawa T, Garber DA, Salama H. Timing, positioning, and sequential staging in esthetic implant therapy: a four-dimensional perspective. *Int J Periodont Restor Dent* 2007; **27**: 313–23.
20. Ostman PO, Hellman M, Albrektsson T, Sennerby L. Direct loading of Nobel Direct and Nobel Perfect one-piece implants: a 1-year prospective clinical and radiographic study. *Clin Oral Implants Res* 2007; **18**: 409–18.
21. Abrahamsson I, Berglundh T, Sekino S, Lindhe J. Tissue reactions to abutment shift: an experimental study in dogs. *Clin Implant Dent Relat Res* 2003; **5**: 82–8.
22. Worhle PS. Commentary on "Scalloped dental implants: a retrospective analysis of radiographic and clinical outcomes of 17 NobelPerfect™ implants in 6 patients". *Clin Implant Dent Relat Res* 2006; **8**: 54–8.
23. Abrahamsson I, Berglundh T, Lindhe J. The mucosal barrier following abutment dis/reconnection: an experimental study in dogs. *J Clin Periodontol* 1997; **24**: 568–72.
24. Lazzara RJ, Porter SS. Platform switching: a new concept in implant dentistry for controlling postrestorative crestal bone levels. *Int J Periodont Restor Dent* 2006; **26**: 9–17.
25. Canullo L, Rasperini G. Preservation of peri-implant soft and hard tissues using platform switching of implants placed in immediate extraction sockets: a proof-of-concept study with 12- to 36-month follow-up. *Int J Oral Maxillofac Implants* 2007; **22**: 995–1000.
26. El Askary AES. Inter-implant papilla reconstruction by means of a titanium guide. *Implant Dent* 2000; **9**: 85–9.
27. Azzi R, Etienne D, Takei H, Fenech P. Surgical thickening of the existing gingiva and reconstruction of interdental papillae around implant-supported restorations. *Int J Periodont Restor Dent* 2002; **22**: 71–7.
28. Han TJ, Klokkevold PR, Takei HH. Strip-gingival autograft used to correct mucogingival problems around implants. *Int J Periodont Restor Dent* 1995; **15**: 404–11.

Chapter 13

Complications of autogenous bone grafting

Craig M. Misch DDS, MDS

Introduction

From a historical perspective autogenous bone has long been considered the gold standard for osseous reconstruction and repair. The use of autogenous bone with dental implants was originally discussed by Brånemark *et al.* in 1975 (1).

Implant success rates in early studies were often lower in reconstructed jaws. Reasons for these compromised results include the use of machined implants, developmental techniques with operator inexperience and simultaneous graft and implant placement. Since the early Swedish studies there have been numerous publications on various techniques using autograft for osseous site development and implant placement. Improvements in implant technology and refinement of surgical methods have resulted in improved outcomes in reconstructed bone.

In many regards autogenous bone grafts remain the gold standard for repair of jaw atrophy and bone defects. Autogenous bone grafting is a well-documented procedure for reconstruction of the atrophic maxilla and mandible for rehabilitation with implant prostheses. Autogenous bone grafting offers a well-proven, predictable method for ridge augmentation and defect repair for dental implant placement (2). However, as with any surgical technique complications can occur. Alveolar ridge augmentation procedures may be more technique sensitive and outcomes more influenced by operator experience (3, 4). Complications from bone graft harvest, graft placement, and implant insertion in augmented sites are reviewed in this chapter.

Proper diagnostic techniques, surgical planning, and careful execution of procedures can prevent many of the potential complications experienced with autogenous bone grafts. Before discussing the etiology, prevention, and treatment of complications related to autogenous grafting, donor sites will be reviewed for the clinician to understand better their advantages, limitations, and inherent complications. Thereafter, detailed discussions of recipient site complications will be covered including a brief summary with take-home hints for etiology, prevention, and treatment. Problems related to patient habits, diseases, and medications are reviewed as related to autogenous grafts only, as this material has been covered in a separate chapter (see Chapter 2).

Donor sites

Selection

Early studies in the treatment of the atrophic maxilla and mandible with dental implants focussed on the use of iliac bone grafts for jaw reconstruction (5). Although the iliac crest is most often used for major jaw reconstruction, it has the disadvantages of the need for a hospital operating room, general anesthesia, possible postoperative hospitalization, and alteration of ambulation. Additional alternative donor sites have been evaluated including the calvarium, rib, proximal tibia, and the maxillofacial regions.

A comprehensive evaluation of the graft recipient site is necessary for planning of the bone graft surgery. The donor site for bone harvest is determined by several factors, including size of the bone defect, quantity of bone needed for the repair, the desire for block or particulate bone and, to some degree, clinician and patient preferences. Selection of a graft donor site that provides adequate bone volume for implant placement in ideal locations for prosthetic support is an important aspect of the diagnostic evaluation. The volume of donor bone for harvest, ranging from largest to smallest, is as follows: posterior ilium, anterior ilium, proximal tibia, calvarium, rib, mandibular symphysis, mandibular ramus, and maxillary tuberosity.

Panoramic and periapical radiographs are used to evaluate the bone defect, surrounding dentition and regional anatomy. Computed tomography (CT) is useful for three-dimensional views of the bone deficiency and can also be used to assess intraoral donor sites. Implant planning software can be used with the scan to evaluate more precisely the reconstructive needs of the patient (6). A stereolithographic model of the jaw can be generated from the scan to plan the case further (7). Mounted

study casts and diagnostic waxing allow the clinician to appreciate the ridge morphology in relationship to planned prosthetic outcome. They also may be used for the fabrication of a radiographic template worn during the CT scan (8). The template reveals the radiopaque outline of the prosthetic tooth position in the tomographic view of the residual ridge (Figs 13.1, 13.2). This allows a determination of graft size requirements and donor site options. A template of the planned prosthetic tooth position is also helpful for use during graft surgery to confirm graft positioning and fulfillment of the grafting requirements.

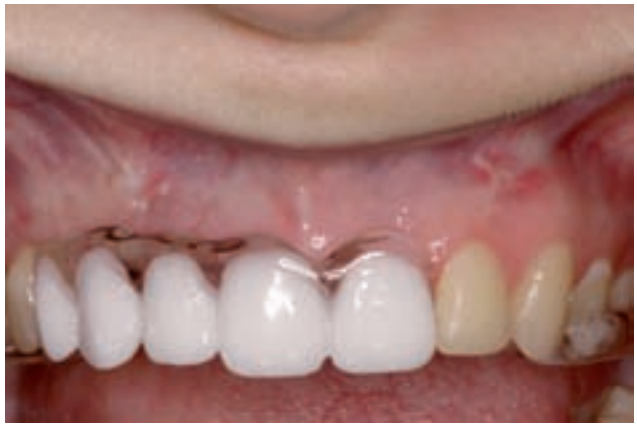


Fig. 13.1 Maxillary trauma patient with radiographic template using barium teeth.

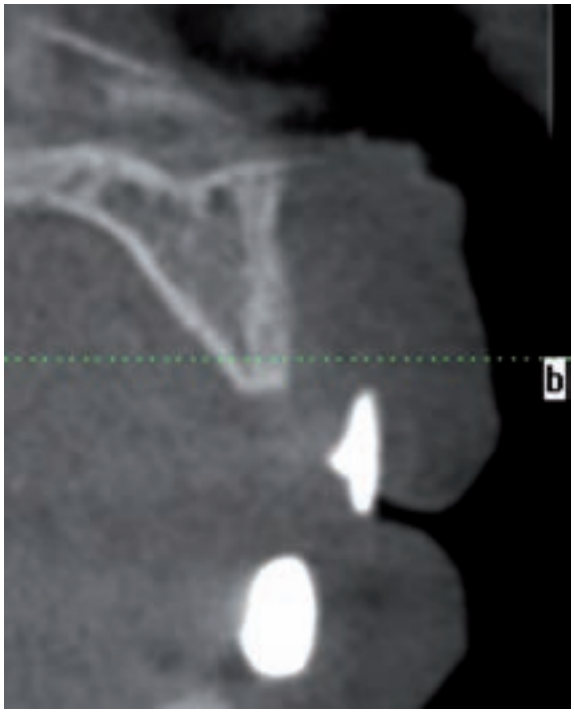


Fig. 13.2 CT scan with radiographic template revealing the relationship between the residual ridge and planned prosthetic tooth position.

Ilium

The grafting of larger areas of bone deficiency often requires bone harvest from the ilium. The ilium is most often reserved for cases requiring large corticocancellous block grafting (Fig. 13.3). In most patients adequate bone may be harvested using an anterior approach to the hip. A posterior approach to the ilium is less often required and is usually reserved for major reconstructive surgery requiring large amounts of cancellous bone. In addition, the need to rotate the patient after posterior bone harvest is an inherent disadvantage. Although posterior bone harvest is reported to result in lower postoperative pain (9), the use of an anesthetic pain pump can minimize the problem with anterior harvest (Fig. 13.4).

There are varying shapes to the blocks that may be harvested from the hip. A reciprocating saw and chisels are used to perform the osteotomies for bone harvest

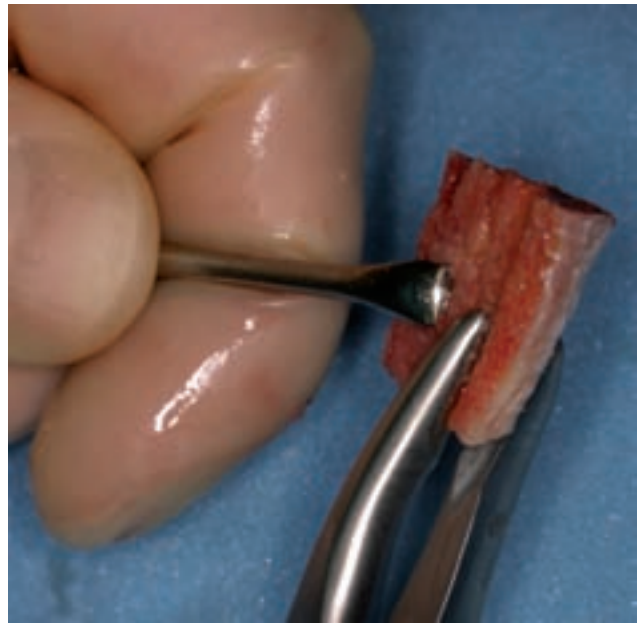


Fig. 13.3 Corticocancellous block bone graft from anterior iliac crest.

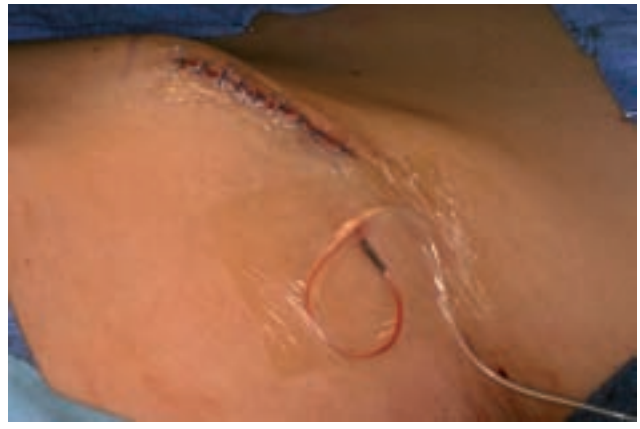


Fig. 13.4 Pain pump catheter inserted through a remote site.

(Figs 13.5, 13.6). For a corticocancellous block from the medial cortex the crestal osteotomy should begin at least 1 cm from the anterior iliac spine. Thicker, tricortical grafts should be taken further from the anterior iliac spine. Otherwise the remaining anterior segment of bone may be weakened and fracture (10). For unicortical bone harvest the iliac crest is cut along its length leaving the opposing cortex intact. When thicker pieces of bone are needed for vertical bone augmentation a tricortical bone graft may be harvested from the entire width of the crest (Figs 13.7, 13.8). The gluteal muscle attachments are reflected from the lateral cortex along the crest of the ilium. This graft geometry is typically used for reconstructing the severely atrophic premaxilla (2). Edges of the iliac cortex should be smoothed with a rasp or file. Following the removal of the bone graft hemostatic materials, such as a sheet of microfibrillar collagen (Avitine) or gelatin, can be placed over the cancellous bone. The use of a pain pump with long-acting local anesthetic has dramatically reduced the level of postoperative pain from the hip area (11). The pain pump catheter is placed into the wound following closure of the periosteal layer. The infusion device delivers controlled amounts of long-acting local anesthetic to the area for improved postoperative pain management. The muscle layers and subcutaneous tissues are closed with Vicryl mattress and interrupted sutures. The skin may be closed with Prolene interrupted sutures or surgical staples. The pain pump is removed a few days after surgery when the local anesthetic has been pumped out. The patient is instructed to avoid full leg weight bearing on the side of graft harvest for 1 week. Crutches or a walker may be used for ambulatory assistance. Using the left hip for harvest allows patients to return to driving earlier. The patient should avoid exercise and heavy lifting for 6 weeks following surgery (12).

Postoperative iliac donor site complications include pain, infection, neurosensory disturbances, seroma, hematoma, infection, gait disturbance, cosmetic deformity, and scarring. The incidence of deep wound infection is very low but superficial skin infections can be slightly more common (13).

Hematoma formation is uncommon and can be avoided with the use of local hemostatic agents after bone graft harvest (14). Seroma formation can be managed by slightly reopening the incision to establish drainage. The

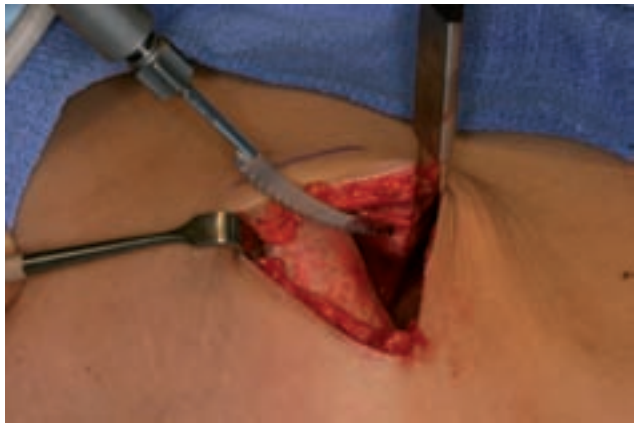


Fig. 13.5 Reciprocating saw used to perform the iliac osteotomies.

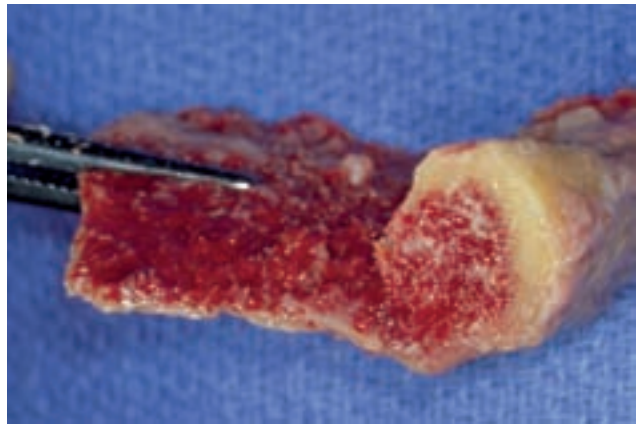


Fig. 13.7 Tricortical graft harvested from the iliac crest.

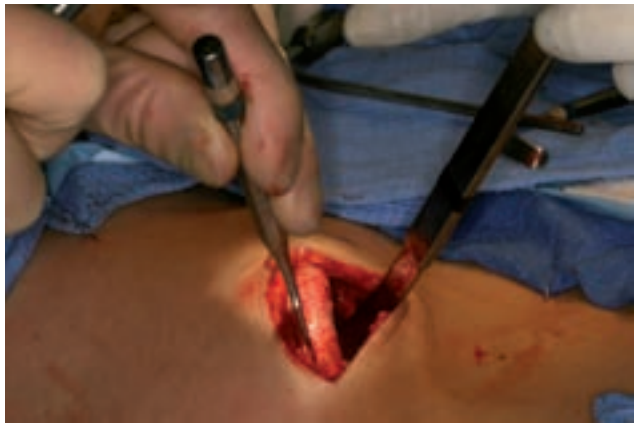


Fig. 13.6 Bone chisels used to harvest the corticocancellous block graft from the ilium.

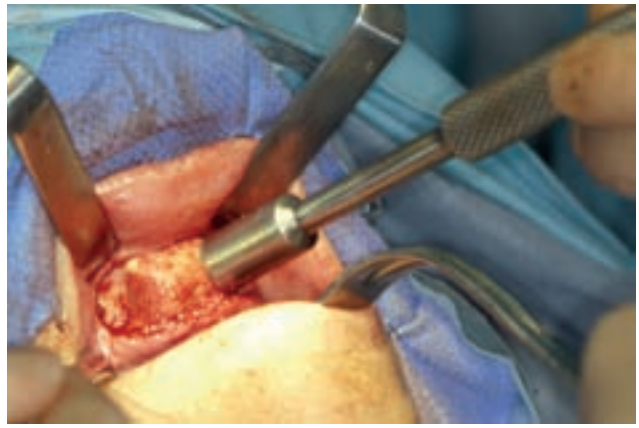


Fig. 13.8 A tricortical graft is applied to the anterior maxilla with a bone tamp.

use of suction drains to prevent these complications is unnecessary.

Neurosensory disturbances are not uncommon following bone graft harvest. The lateral cutaneous branch of the iliohypogastric nerve courses across the iliac crest and can be incised or retracted during surgery. Hypoesthesia may be noted on the lateral thigh and buttocks. The lateral femoral cutaneous nerve crosses along the iliac fossa and runs below the anterior iliac spine. This nerve may be damaged during the incision or during medial retraction of the iliacus muscle. The incidence of nerve injury is approximately 10% and may be related to the size of the graft harvest (15). Nerve injury results in paresthesia of the skin overlying the lateral thigh. The initial incision should be made 1–2 cm from the anterior superior iliac spine to avoid nerve transection, and gentle retraction of the iliacus muscle is advised (Fig. 13.9). Gait disturbance is usually transient until muscle repair is complete. The incision is approximately 4 cm in length and within the bikini line so scarring is of less concern. In patients prone to hypertrophic scar formation silicone sheeting or steroid injections may be necessary.

Tibia

The proximal tibial metaphysis provides an excellent source of cancellous bone for grafting (2, 16–18). This donor site offers up to 40 ml of cancellous bone with low reported morbidity (16, 17). An advantage of this donor site it that the surgery may be performed in an office environment. Most patients prefer intravenous deep or conscious sedation. The most common approach to this donor site is laterally at Gerdy's tubercle, a bony protuberance located 1.5 cm below the articulating surface of the tibia (16). However, a medial approach to the tibia has also been proposed (19). The leg is elevated with a rolled towel or firm pillow and the knee is slightly bent. The leg is shaved and the skin is prepped with an antimicrobial solution (povidone–iodine or chlorhexidine). Sterile drapes are positioned to isolate the surgical field and the surgical team should follow strict aseptic technique including sterile gowns and gloves. A sterile surgical marking pen is used to plan the incision and local anesthetic with a vasoconstrictor is infiltrated along the site. The local anesthetic needle is then directed to the bone for additional infiltration over the area. A 2–3 cm oblique incision is made through the skin on the anterolateral aspect of the leg directly over Gerdy's tubercle (17) (Fig. 13.10). No major nerves or arteries are located in this site. As such, placement of a tourniquet is usually unnecessary and bleeding is controlled with electocautery. After incising through the subcutaneous and fascial layers of the iliotibial tract the periosteum is visualized. An oblique incision is made over the bone with short inferior releasing incisions. The periosteum is reflected to expose the cortex of the tibia. Rake retractors are helpful in reflecting the dense tissue flaps. The 1.5 cm opening through the cortical bone is made with a carbide fissure bur (no. 702). Alternatively, a large trephine bur (10 mm) may be used (Fig. 13.11). The surgeon should direct the bur medially and inferiorly to avoid the knee

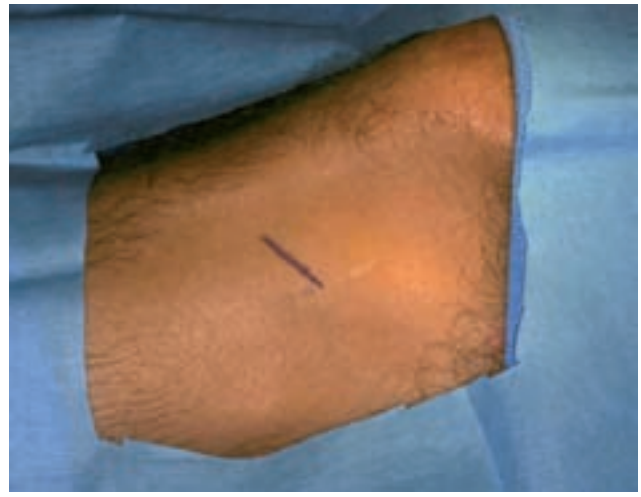


Fig. 13.10 The tibial incision is made over Gerdy's tubercle.

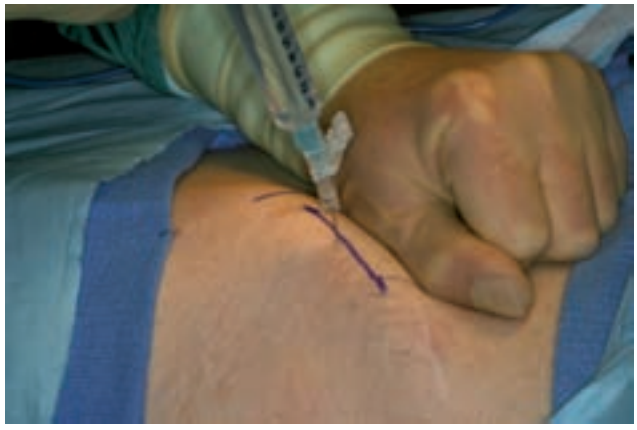


Fig. 13.9 The abdominal skin is stretched medially and the incision is outlined 1 cm from the anterior iliac spine.

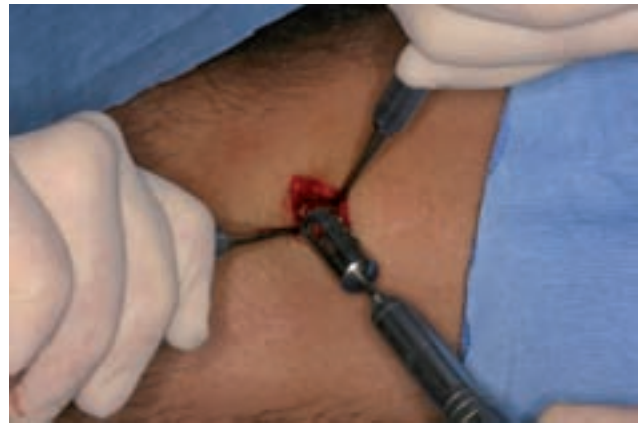


Fig. 13.11 A trephine bur is used to remove the cortical plug and gain access to the cancellous bone.

joint. The cortex is fairly thin so the block piece of cortical bone may be pried from the donor site and placed aside for reconstruction the ridge defect (Figs 13.12, 13.13). The cancellous bone is harvested using orthopedic bone curettes or a no. 2–4 Molt curette. If needed, hemostatic agents, such as microfibrillar collagen (Avitine), may be placed into the bony void. The wound is closed in layers with resorbable sutures (3-0 Vicryl). The skin is closed with sutures (5-0 prolene) or staples. Antibiotic ointment is applied and the knee is wrapped with an elastic pressure dressing. Patients are encouraged to keep the leg elevated and apply ice. They may begin ambulation on the donor leg following the surgery but should avoid full weight bearing for a few days. Although normal activities can be resumed thereafter, the patient should avoid strenuous exercise for 4–6 weeks.

Postoperative pain from tibia bone harvest is well managed with moderate narcotic analgesics. Ecchymosis of the leg distal to the donor site is quite common. There has been a low reported incidence of significant complications with this procedure (16–18, 20). Complications may include hematoma formation, wound dehiscence, infection, and fracture. Although quite rare, most cases of tibia fracture are due to a bony access too low on the leg (21) (Fig. 13.14).

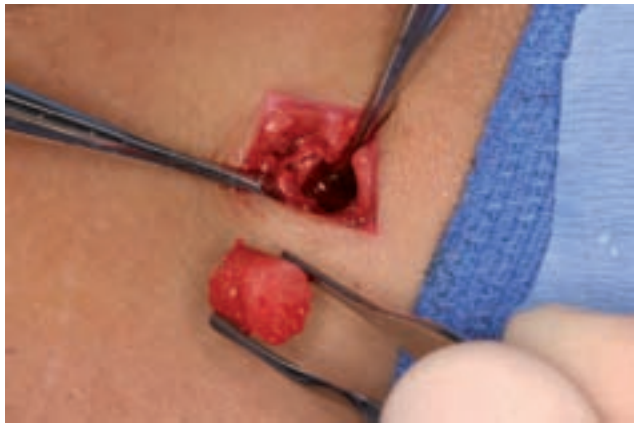


Fig. 13.12 The cortical plug is removed from the tibia.

Fig. 13.13 The cortical plug and cancellous bone harvest.

Mandibular symphysis

The symphysis of the mandible has been used extensively for sinus and onlay bone grafting (22–28). Techniques to harvest block or particulate bone grafts from the anterior mandible have been reported. The symphysis donor site offers the greatest volume of intraoral bone (Fig. 13.15). The average interforaminal distance is approximately 5 cm and the depth of the anterior mandible usually exceeds 1 cm (29). A CT scan or panoramic radiograph is used to evaluate the available bone in this donor site. A lateral cephalometric radiograph can be useful to determine the anteroposterior dimension of the anterior mandible. Periapical radiographs give a more accurate measurement of the tooth root lengths.

The ease of surgical access is one of the main advantages of the symphysis region. Bilateral mandibular blocks and local infiltration in the anterior mandible are administered using 2% lidocaine, 1:100 000 epinephrine. Exposure of the symphysis may be obtained through a sulcular or vestibular incision. The vestibular incision is made in the mucosa between the cuspid teeth approximately 1 cm from the mucogingival junction (Figs 13.16, 13.17). Limiting the distal extent of the incision will

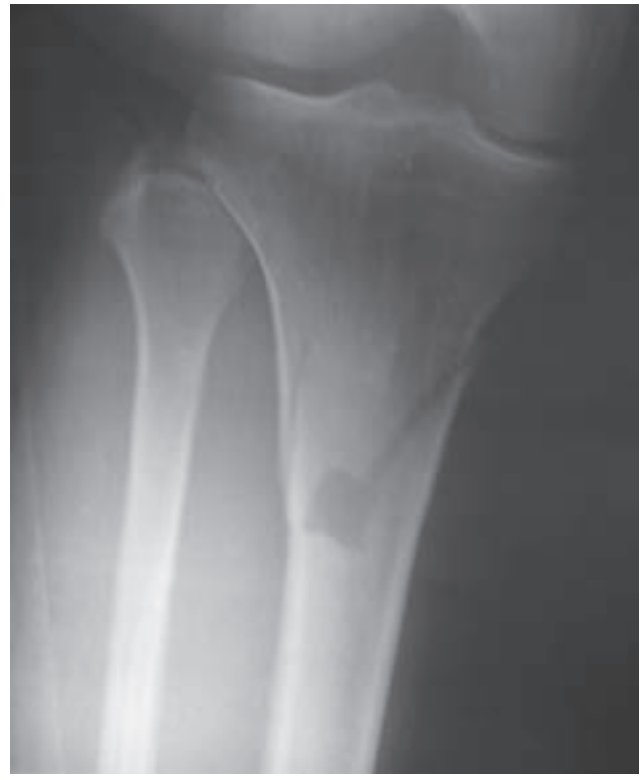


Fig. 13.14 A rare fracture of the tibia from the clinician harvesting too low on the leg.

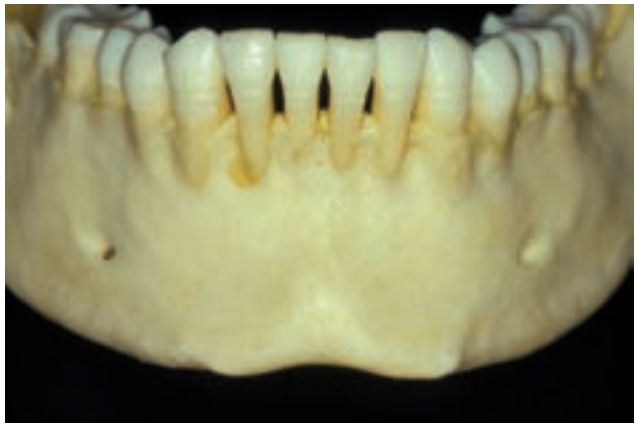


Fig. 13.15 A dry specimen reveals the significant amount of bone that may be harvested from the mandibular symphysis.

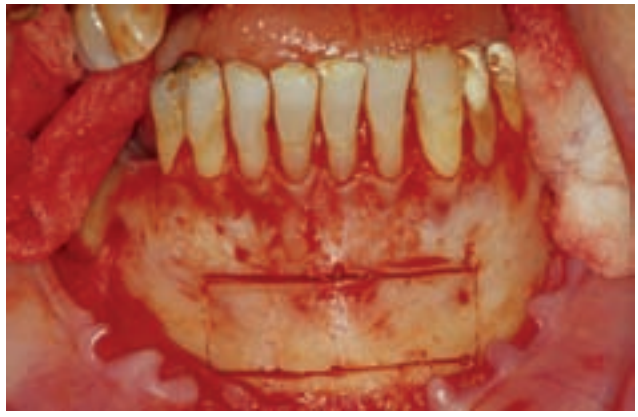


Fig. 13.18 The sulcular approach to mandibular symphysis raft harvest.

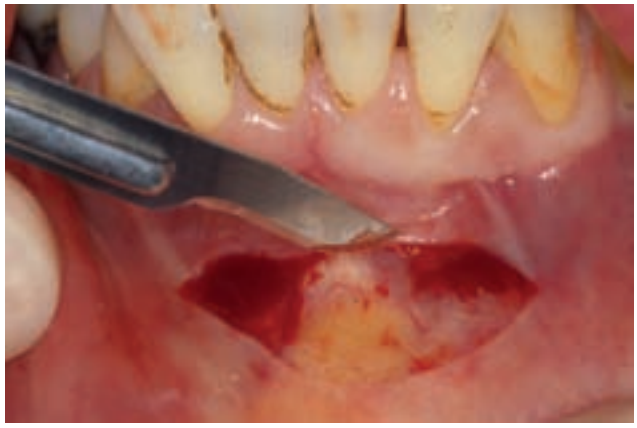


Fig. 13.16 The vestibular incision is made in the mucosa between the cuspid teeth.

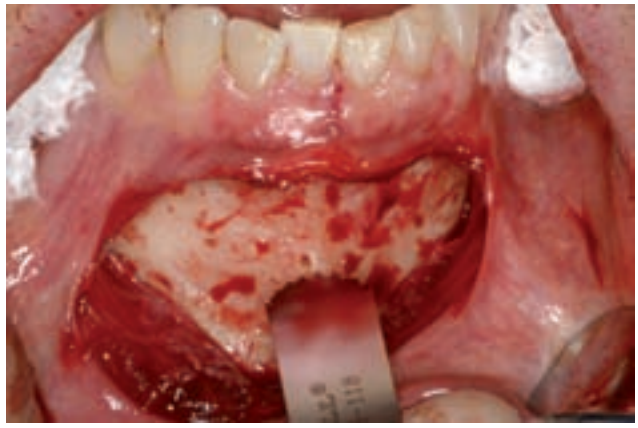


Fig. 13.19 A sagittal saw is used to perform the osteotomies in the symphysis.

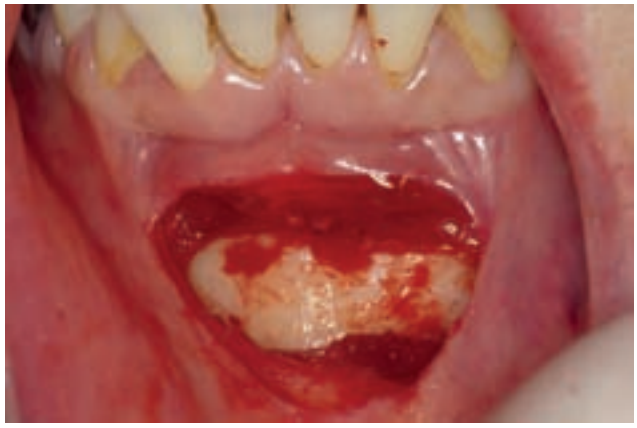


Fig. 13.17 The mucoperiosteal reflection exposes the mandibular symphysis through the vestibular approach.

reduce the risk of mental nerve injury. The symphysis can easily be accessed from this limited incision as the flaps can be retracted. A vestibular approach allows easy access but produces more soft-tissue bleeding and possible intraoral scar formation. The sulcular approach should not be used when mucogingival defects are present and may result in gingival recession. The sulcular incision should extend to the premolar regions bilaterally (Fig. 13.18). A mucoperiosteal flap is reflected to expose the mental foramina and the inferior border of the mandible (pogonion). Additional local anesthesia is often needed at the base of the mandible to block cervical innervation.

After the symphysis region is exposed, the osteotomies for graft harvest are planned. The dimensions of the graft are determined by the bone volume needed to reconstruct the recipient site. Osteotomies should be kept at least 5 mm from the root apices and the mental foramina (23, 30, 31). In most cases the inferior and lingual cortices of the mandible are left intact. The facial cortex is thick and the underlying cancellous bone is usually dense. The osteotomies may be made with a carbide fissure bur (no. 557 or 701) in a surgical handpiece or sagittal saw (Fig. 13.19). Following an osteotomy through the outer cortex, and into the cancellous bone, the graft is removed with a chisel (Fig. 13.20). A unibeveled chisel is tapped along the osteotomies, with the exception of the inferior border, to fracture the block from its base. The block bone graft may also be harvested in segments by sectioning

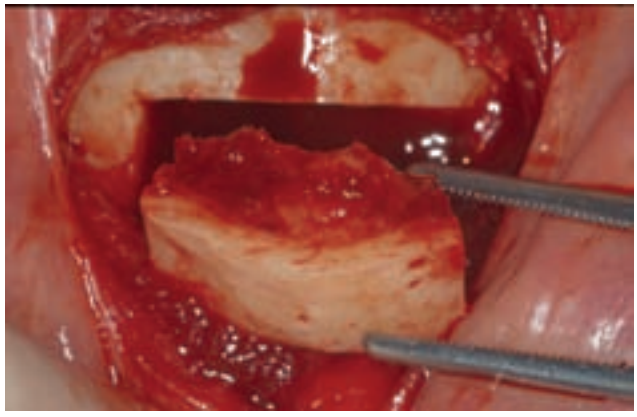


Fig. 13.20 Harvesting the thick corticocancellous block bone graft from the symphysis.

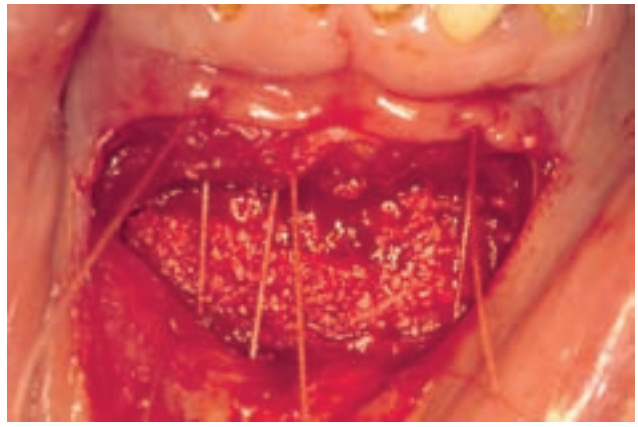


Fig. 13.22 The symphysis donor site is closed in a layered approach with submerged sutures.

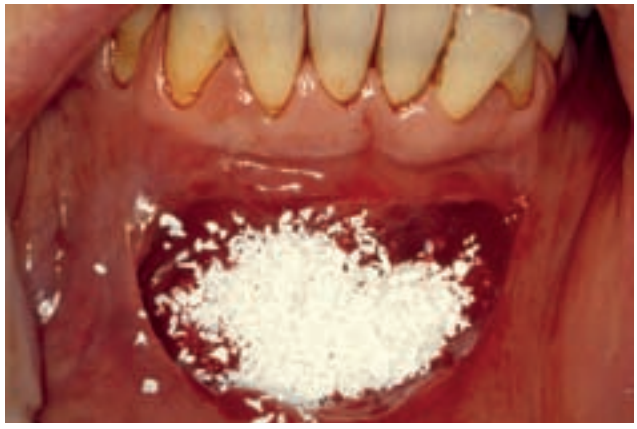


Fig. 13.21 The symphysis donor site is filled with bovine hydroxyapatite.

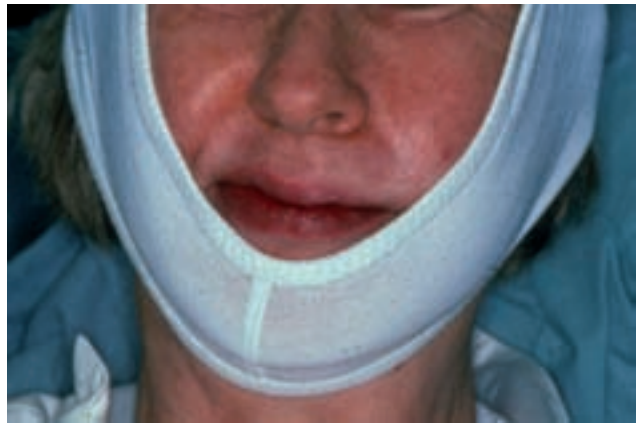


Fig. 13.23 A pressure dressing is applied to the chin to reduce edema and maintain incision closure.

the rectangular piece in the midline. Two bone blocks are often easier to harvest as the second block can be fractured from its lingual base with the chisel. Some additional cancellous bone may be procured with a curette, chisel, ronguer, or trephine, after the block is removed, but the volume is meager (29). Following the removal of the block graft hemostatic materials, such as collagen or gelatin, may be placed over the cancellous bone. When larger bone grafts are harvested the donor site should be filled with a bone substitute, such as resorbable hydroxyapatite, to maintain facial contour (23) (Fig. 13.21). Smaller or particulate bone grafts may be procured using trephine burs, bone collection traps, or bone scraping instruments (32–34). Closure of the donor site is typically performed after the graft is inserted into the recipient site. This minimizes the time between graft harvest and placement. The mucosa superior to the vestibular incision is reflected to reduce tension on the flaps from edema and lip movement. The vestibular incision is closed in layers using resorbable sutures (Fig. 13.22). The deeper layers may be sutured with 4-0 Vicryl and the superficial mucosa can be closed primarily with 4-0 chromic gut. Postoperative pressure dressings are used over the chin to reduce edema, hematoma formation, and incision line opening (Fig. 13.23).

The mandibular symphysis is associated with a higher incidence of postoperative complications than other maxillofacial donor sites (26, 35–37). Altered sensation of the lower anterior teeth is a relatively common postoperative symptom when bone blocks or trephine cores are removed (23, 26, 35–37). The contents within the incisive canal of the symphysis that innervate the teeth are disrupted during bone harvest (Figs 13.24, 13.25). Patients describe dullness in sensation of the incisors, which usually resolves within 6 months. The need for endodontic treatment of anterior teeth is very rare. Discoloration of the lower incisors from pulpal injury and deposition of secondary dentin has been noted (Fig. 13.26). Neurosensory disturbances in the chin region also may be encountered, even when a sulcular incision is used (35–37). The incidence of temporary mental nerve paresthesia for symphysis graft patients is usually low but has been found to be as high as 43% (35) (Fig. 13.27). Meteorotropism of the chin has also been reported (35)

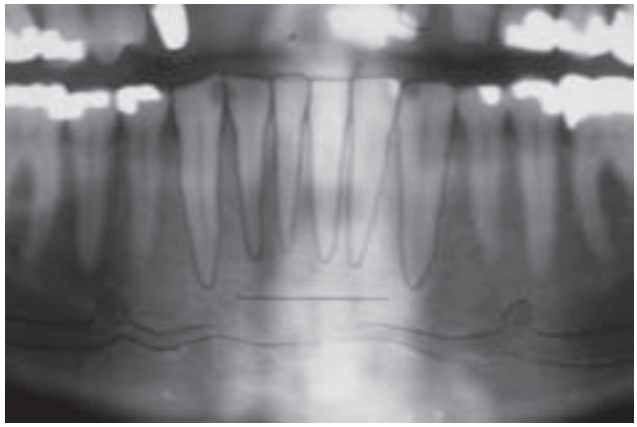


Fig. 13.24 A panoramic radiograph reveals the incisive canal.

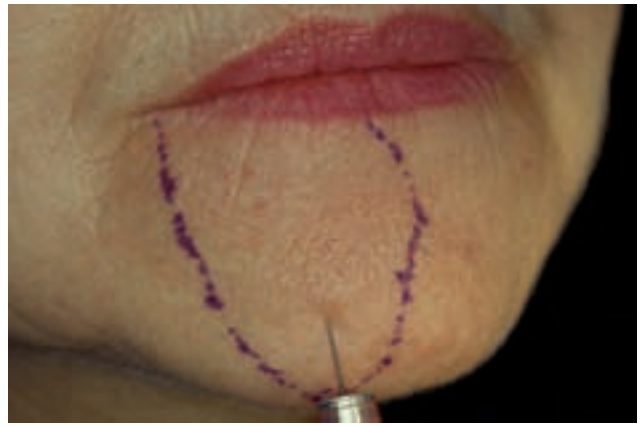


Fig. 13.27 Neurosensory deficit after symphysis graft harvest.

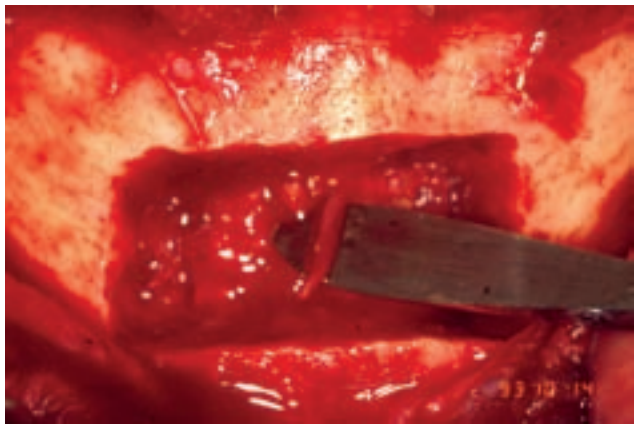


Fig. 13.25 The incisive branches of the inferior alveolar nerve are often damaged during symphysis graft harvest.

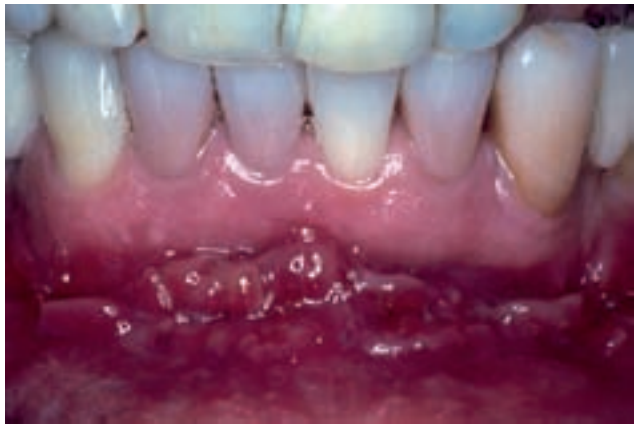


Fig. 13.26 The incisors are discolored after chin bone harvest.

in cold weather climates. Although the vast majority of these nerve injuries recover they are disconcerting to patients. It is prudent to discuss the possibility of temporary altered sensation of the teeth and chin before surgery. Although no postoperative alteration in soft-tissue chin contour has been reported, patients are often concerned with the possible esthetic consequences of bone removal from this area (35). Radiographic evidence of incomplete bony regeneration has been reported in elderly patients (38). Filling the donor site with a resorbable bone substitute, such as bank or bovine bone, can help alleviate the patient's concerns (23). Ptosis of the chin has not occurred and can be prevented by avoiding complete degloving of the mandible (39). Fracture of the mandible has been reported through the lingual cortical plate after chin graft harvest (40). As previously noted, it may also occur when the graft harvest encroaches on the mandibular border. Postoperative pain may be significant with chin bone harvest (35). The postoperative administration of mandibular nerve blocks with long-acting local anesthetic, such as bupivicaine, is useful in postponing the onset of pain and allows postoperative analgesics to be absorbed. Prophylactic non-steroidal medications, such as ibuprofen, are given before surgery to manage pain and swelling.

Mandibular ramus

The posterior mandible is an excellent donor site for bone harvest and this region offers several advantages over the symphysis (26, 28, 37, 41–43). A CT scan or panoramic radiograph is used to evaluate the bony anatomy including the ramus, external oblique ridge, and mandibular canal. A mandibular block is administered using 0.25% bupivicaine, 1:200 000 epinephrine. Buccal infiltration in the posterior mandible is performed with 2% lidocaine, 1:100 000 epinephrine. The incision design for access to this region differs for block and particulate bone harvest. When taking a block graft the incision is made similar to one used in third molar removal. A sulcular incision is made along the posterior teeth. The incision is continued posteriorly and laterally at a 45-degree angle from the distobuccal aspect of the second molar or the base of the retromolar pad if no molar is present. The incision extends superiorly along the

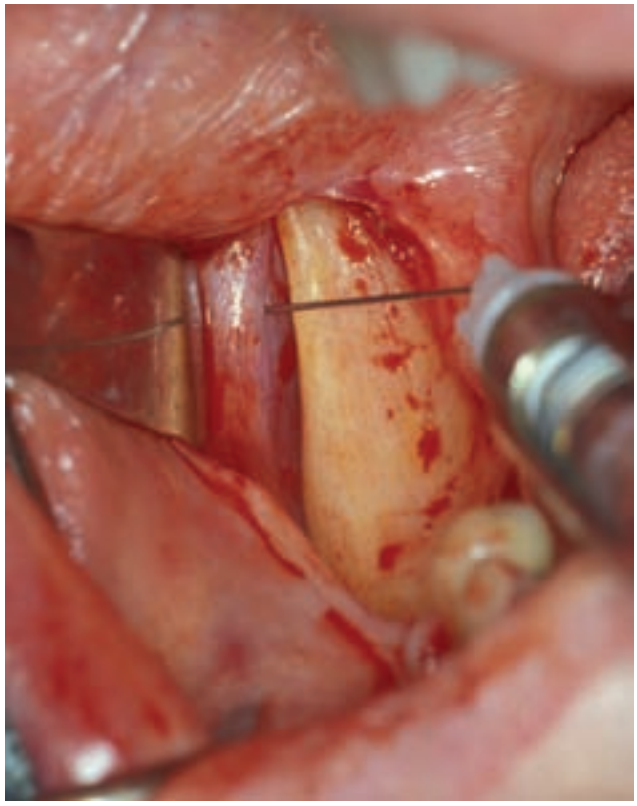


Fig. 13.28 Local anesthetic is injected over the masseter muscle to block cervical innervation.

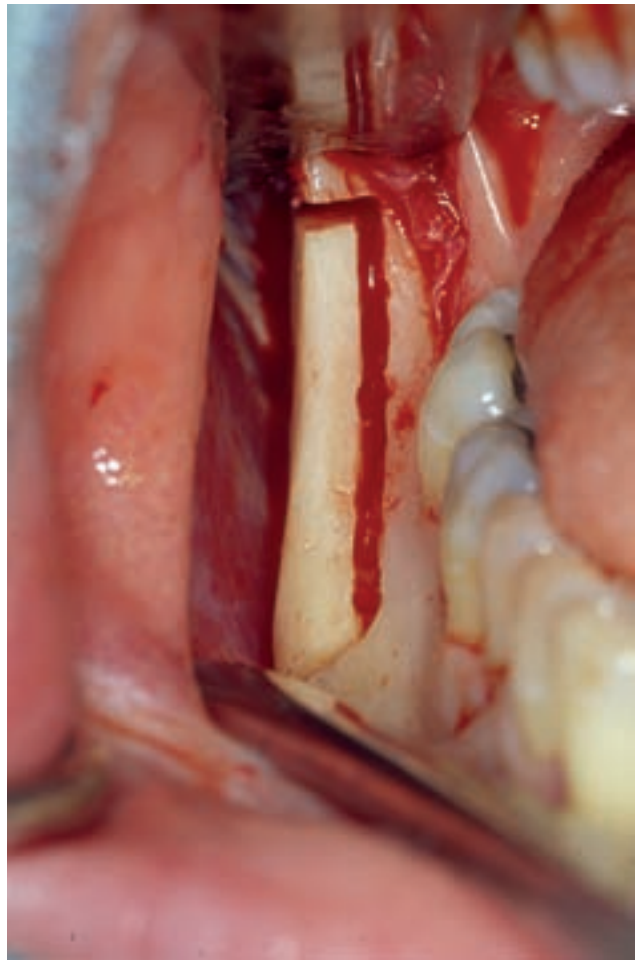


Fig. 13.29 The ramus bone graft osteotomies.

ascending ramus. Following the incision a mucoperiosteal flap is reflected to expose the lateral ramus and body of the mandible. The masseter muscle is reflected laterally with a large retractor to form a large open pocket. Additional local anesthesia is often required in this area to block cervical innervation (Fig. 13.28). The limits of the ramus area are dictated by clinical access in addition to the coronoid process, molar teeth and inferior alveolar canal. The average anteroposterior dimension of the mandibular ramus is 30 mm and the lingula is typical in the posterior third (44).

Four osteotomies are made to harvest a block bone graft: external oblique, superior ramus, anterior body, and inferior (43) (Fig. 13.29). The length of the osteotomies is determined by the bone volume needed to reconstruct the site. The cortical cuts are made with a carbide fissure bur (no. 557 or 701) in a straight handpiece under sterile saline irrigation. A piezoelectric unit may also be used and can minimize the width of the bone cuts. The external oblique cut is made along the anterior border of the ramus approximately 4–6 mm medial to the external oblique ridge. This osteotomy can extend as high as the base of the coronoid process and anteriorly up to the first molar area. This can produce a graft that may approach up to 40 mm in length. The superior ramus cut is made through the lateral cortex of the ramus and perpendicular to the external oblique cut. It may extend as far posteriorly on the ramus as the opposing lingula on the medial ramus. However, the length of this cut is typically about 10 mm. The anterior body cut may often extend over the path of the mandibular canal. Although the buccolingual position of the mandibular canal is variable, the distance from the canal to the medial aspect of the buccal cortical plate (medullary bone thickness) was found to be greatest at the distal half of the first molar (mean 4.05 mm) (45) (Fig. 13.30). Therefore, the anterior body cut should be made in this area and not in the third molar region where the canal is closer to the buccal surface. This anterior body cut is progressively deepened until bleeding from the underlying cancellous bone is visible. The inferior osteotomy is only a partial thickness cut made with a round carbide bur (no. 8). It connects the inferior aspects of the superior ramus and anterior body cuts. This osteotomy on the lateral aspect of the ramus parallels the external oblique cut and creates the base of the rectangular bone block. It extends only partially through the cortex and creates a line of fracture. It is important to limit the depth of this cut as the mandibular canal may notch the inner surface of the buccal cortex in the third molar

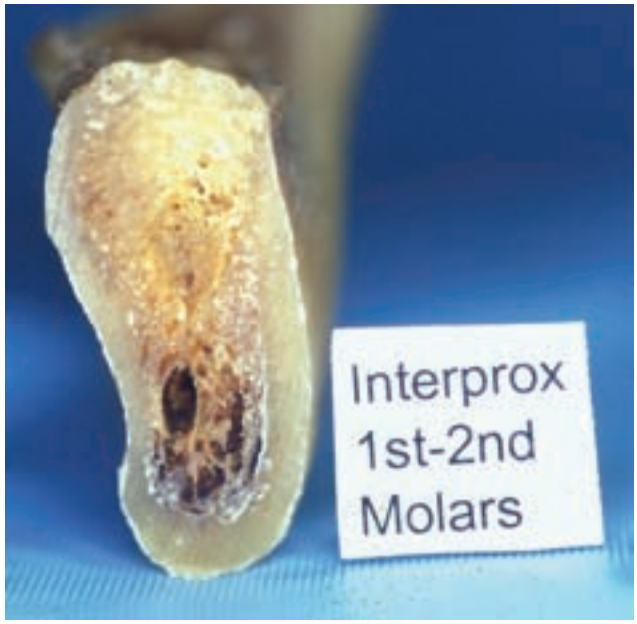


Fig. 13.30 A dry specimen reveals the medial position of the mandibular canal in relation to the buccal cortex.

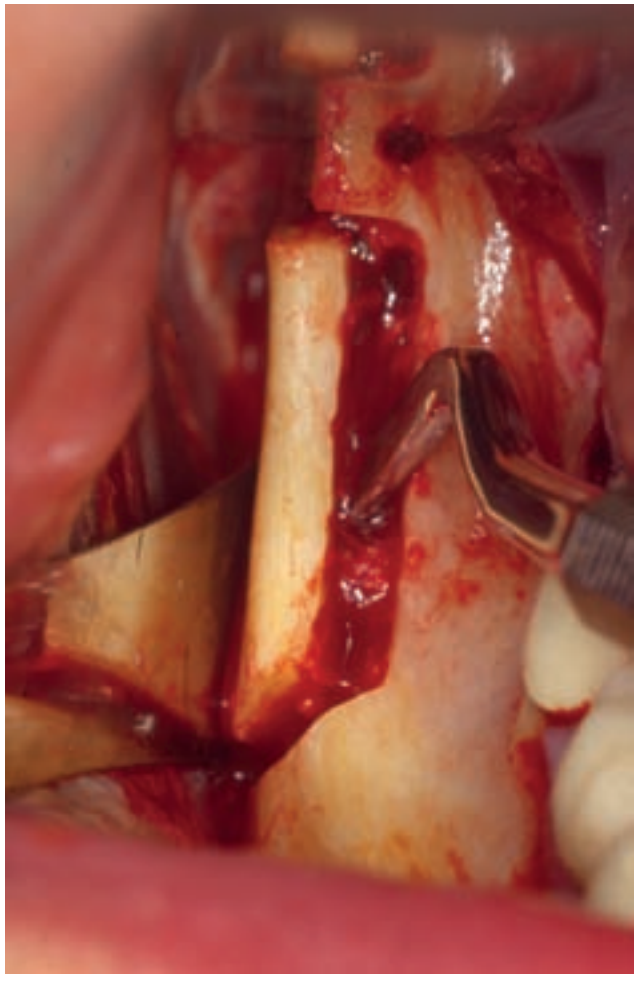


Fig. 13.31 A Potts elevator is used to pry the ramus graft from the mandible.

area (46). The block graft is then removed with a chisel wedged within the external oblique osteotomy. Care should be taken to parallel the chisel with the lateral surface of the mandible and limit the depth of penetration. An alternative technique is to insert an extraction elevator and pry the graft free (Fig. 13.31). This donor site is not augmented with bone substitutes as the inferior alveolar nerve may be exposed and irritated by the graft particles. The incision is closed primarily with resorbable sutures (4-0 chromic gut). A rectangular piece of bone approximately 4 mm in thickness may be harvested from the ramus. This morphology is well suited for veneer grafting to gain additional ridge width, or the block may be particulated in a bone mill.

The mandibular ramus is a convenient donor site for bone harvest in conjunction with third molar removal (47). This is often planned for the repair of alveolar deficiencies from congenitally absent teeth in young adults. If the third molar is partially erupted the tooth is removed before bone harvest. If the molar is bony impacted then the block graft is harvested and the tooth can be removed laterally through the donor site. The cortical block graft can be used to reconstruct the ridge deficiency.

The posterior mandible is the preferred area for harvesting large amounts of particulate bone with a scraper device (34) (Fig. 13.32). The initial incision for this approach is made in the buccal vestibule, similar to one used in sagittal split osteotomies. It is made just lateral to the external oblique ridge and extends the length of the molar regions. This incision design requires minimal time to reflect and gain access to the mandible and is equally easy to close. A larger area of mandibular exposure allows longer strokes with the scraper blade and expedites graft harvest. The dense cortical bone should be repeatedly lubricated with sterile saline during the scraping. Routinely, 4 ml of particulate autograft may be harvested from this area. There is minimal morbidity in harvesting bone from the cortical surface with a scraper blade.

Compared with the symphysis region, the ramus donor site is associated with a much lower incidence of complications (26, 37). Patients have shown less concern with bone removal from the ramus area. The masseter muscle provides soft-tissue bulk and augmentation of this donor site has been unnecessary. Neurosensory disturbances from bone harvest have not been encountered. However, the potential for damage to the inferior alveolar nerve, as opposed to its peripheral mental branches, is of greater concern with the ramus graft technique. As previously described, it is important to plan osteotomies in the posterior mandible around the position of the mandibular canal. Although the neurovascular bundle may be exposed, the harvest of the graft does not injure the structure (Figs 13.33, 13.34). In contrast to the common complaint of altered sensation of the incisors with

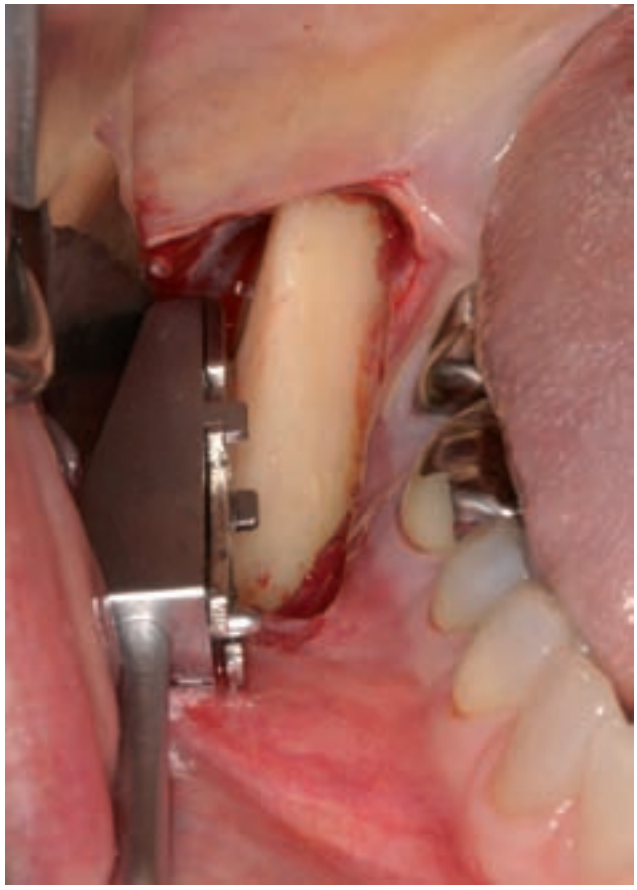


Fig. 13.32 A bone scraping device is used to harvest particulate bone from the ramus region.

chin bone harvest, no ramus graft patients have noted numbness of their molar teeth (26, 37). Although the posterior incision along the external oblique ridge could possibly damage the buccal nerve, reports of sensory loss in the buccal mucosa are rare and will most likely go unnoticed (48). Ramus graft patients appear to have fewer difficulties with managing postoperative edema and pain compared with chin graft surgery (26, 37). Patients may experience trismus after surgery and should be placed on postoperative glucocorticoids and non-steroidal anti-inflammatory medications to help reduce dysfunction. The mandibular ramus has significantly less morbidity than the symphysis and has become the preferred donor site of many clinicians (26, 34, 36, 37).

Maxillary tuberosity

Although the maxillary tuberosity offers a smaller amount of bone than other donor sites, the softer consistency of the graft is often favorable for filling bone defects (49). The bone in the tuberosity area is porous and the outer cortical layer is thin. As the tuberosity is in the same surgical field when performing a lateral approach to sinus grafting it should be routinely considered for bone harvest (50). The amount of bone that may be obtained can be deceptive as the mucosa over the tuberosity is usually much thicker. A periapical or panoramic radiograph can be used to assess the underlying bone. CT scanning of the maxillary sinus region can allow three-dimensional quantification of the area. The anatomic limitations of tuberosity bone harvest include the maxillary sinus, pterygoid plates, molar teeth, and the greater palatine canal. To gain access to the area for bone harvest an incision is made along the ridge crest over the tuberosity. A vertical releasing incision is made along the lateral aspect of the posterior maxilla. Mucoperiosteal reflection exposes the tuberosity, ridge crest and lateral maxilla. The palatal tissue should also be elevated to reveal the entire width of the tuberosity. The graft may be harvested with a chisel or ronguers. The chisel edge should be kept slightly superficial to the maxilla to shave off pieces of tuberosity bone and prevent inadvertent sinus communication (51) (Figs 13.35, 13.36). A chisel can also be used along the posterior lateral maxilla to obtain a thin piece of cortical bone used to cover the window after grafting of the sinus floor. If perforation of the max-

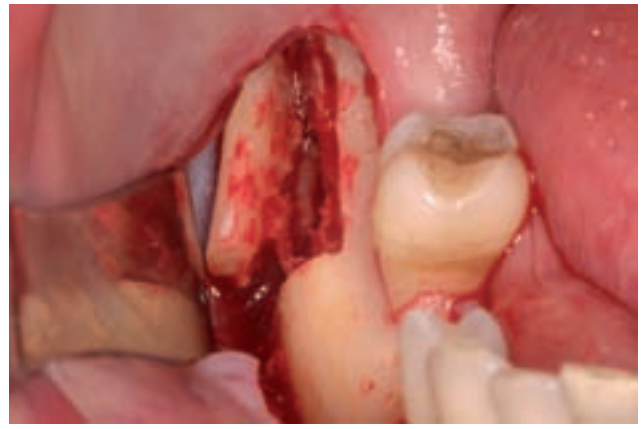


Fig. 13.33 Removal of the ramus bone graft reveals the neurovascular bundle.

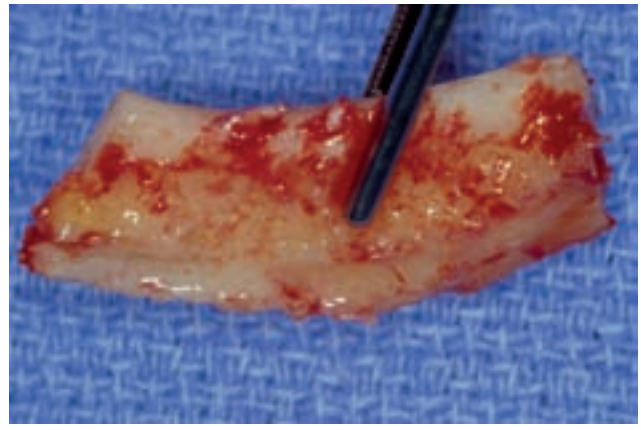


Fig. 13.34 The buccal wall of the mandibular canal is seen within the ramus graft.

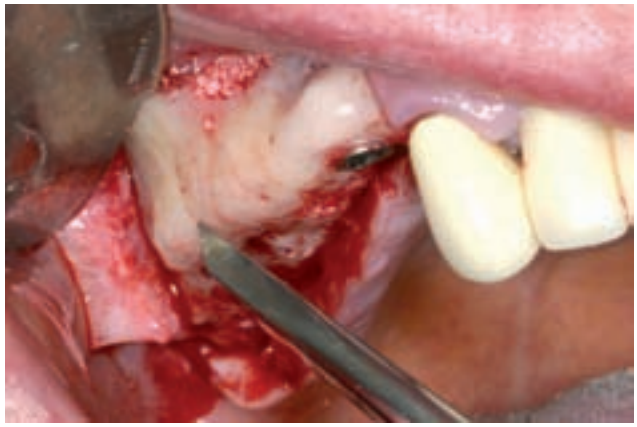


Fig. 13.35 A chisel is used to harvest bone from the maxillary tuberosity.

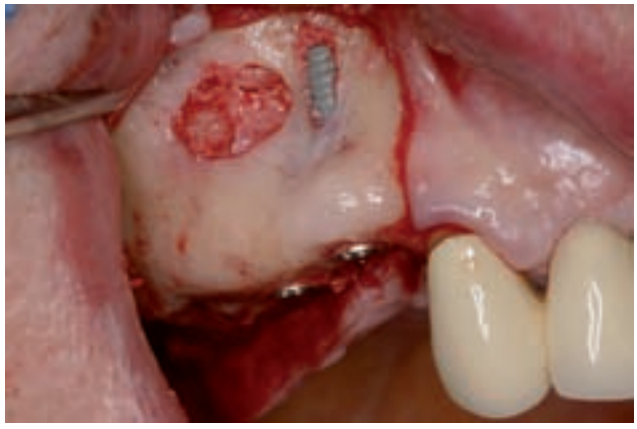


Fig. 13.36 The particulate tuberosity bone is used to graft the maxillary sinus floor.

illary sinus occurs it is unlikely to cause a postoperative problem as the thick soft tissue in the posterior maxilla is closed over the site.

Recipient site complications: early healing complications

Graft contamination

To maintain cellular viability bone graft should be stored in sterile normal saline after harvest, rather than on a moist sponge or towel (52). The hypotonicity of sterile water can cause cell lysis. Minimal time should elapse between graft harvest and placement. The surgeon must protect the graft from inadvertent contact with the non-sterile environment. Aseptic surgical conditions and working over sterile drapes are advised. A separate closed container with sterile saline is used to protect the graft during site preparation. The bone graft should always be held with a bone clamp or Allis forceps during transfer and manipulation rather than using gloved fingers (Fig. 13.37). The risk of graft contamination by

Fig. 13.37 Allis forceps are used to securely handle the bone graft.

glove powder is also a concern (53). If the graft is displaced onto a non-sterile surface it is considered contaminated. Although many surgeons have attempted to clean contaminated grafts with autoclaving, antiseptic, or antibiotic solutions there is little research on this topic. Soaking the graft in 10% povidone–iodine solution for 10 minutes has been found to eliminate surface bacteria without altering the histologic integrity of the graft (54). However, this may alter the osteogenic and osteoinductive properties of the graft. If possible, additional bone should be harvested and the contaminated graft disposed. Preventing this complication is of utmost importance.

- *Complication*: graft contamination.
- *Etiology*: mishandling graft.
- *Prevention*: sterile drapes, use of bone clamp or Allis forceps, separate protected graft container, remove powder on surgical gloves.
- *Treatment*: povidone–iodine, reharvest additional graft.

Wound dehiscence

Complete flap coverage and tension-free closure are essential to the successful incorporation of the bone graft. Incision line opening with graft exposure is the most common recipient site complication with onlay bone augmentation. Revascularization of the bone graft is necessary for incorporation into the recipient site. Therefore, exposure of the bone graft is detrimental to the prognosis of the graft and often leads to graft failure. The clinician should take all possible precautions to prevent this devastating complication from occurring. Early in an operator's learning curve of onlay grafting proce-

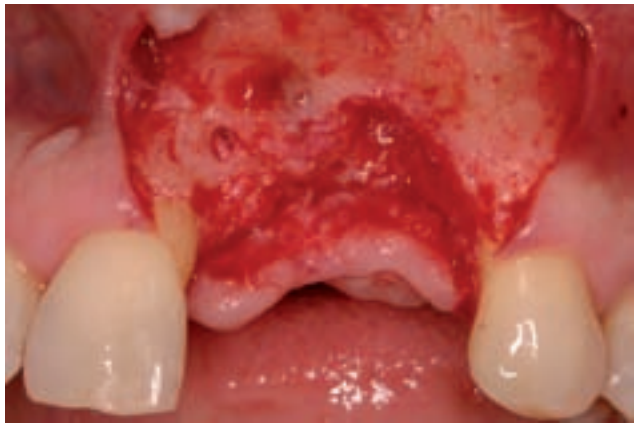


Fig. 13.38 The bone loss on the central incisor bordering the defect limits the vertical augmentation.

dures the most common cause for incision line opening is a lack of tension-free flap adaptation. As experience is obtained in managing the soft-tissue flaps this complication occurs with low frequency. As such, early in the learning curve a clinician should not attempt to treat more complicated cases such as advanced atrophy or vertical bone augmentation.

The periodontal health and endodontic status of teeth adjacent to the graft recipient site should be evaluated before grafting. It may be prudent to extract hopeless teeth before grafting, especially if infection is present (55). The marginal bone height on the teeth bordering the bone defect determines the level that may be achieved with vertical bone augmentation (Fig. 13.38). It may be necessary to extract stable teeth if they have bone loss that limits the augmentation requirements.

The clinician should inspect the planned graft recipient site for soft-tissue character including quality, amount of keratinized mucosa, tissue thickness, high muscle attachments, frenum, and scarring. It is preferred to correct soft-tissue problems before bone grafting surgery. Any inflammation of the overlying soft tissues should be resolved before surgery. Soft-tissue-borne prostheses may require adjustment and presurgical tissue conditioning with liners. Poor hygiene under pontics should be recognized and managed before surgery. Teeth requiring extraction directly within the bone graft site should be planned for removal several weeks before surgery.

Soft-tissue grafting is often recommended before the onlay bone graft surgery (Figs 13.39–13.42). Soft-tissue grafting provides better tissue quality and thicker tissue to maintain flap closure. Short vestibular depth or muscle attachments may also be managed during the soft-tissue surgery. To increase the zone of keratinized tissue, autogenous free gingival grafts from the palate are favored over cadaveric tissue such as bank dermis as they revascularize more quickly. Scar tissue can limit flap mobility and impede vascular supply to the incision. When present in the recipient site excision of cicatricial tissue should be considered for replacement with a gingival graft. If the overlying mucosa is thin in the recipient site then the soft-tissue volume may be enhanced with an interpositional palatal connective tissue graft. In cases where the clinician is only augmenting flap thickness

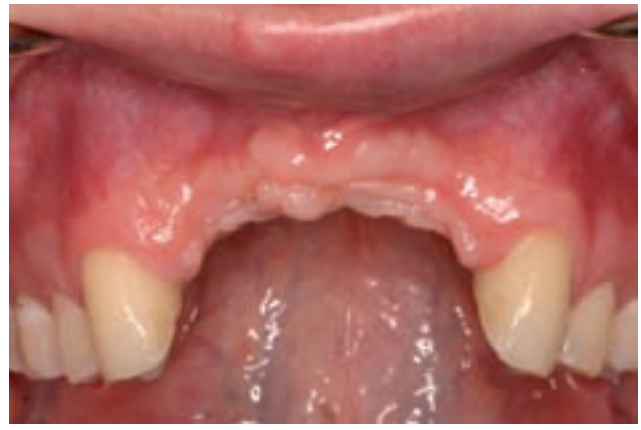


Fig. 13.39 The patient had traumatic tooth loss and failed attempts at ridge repair.

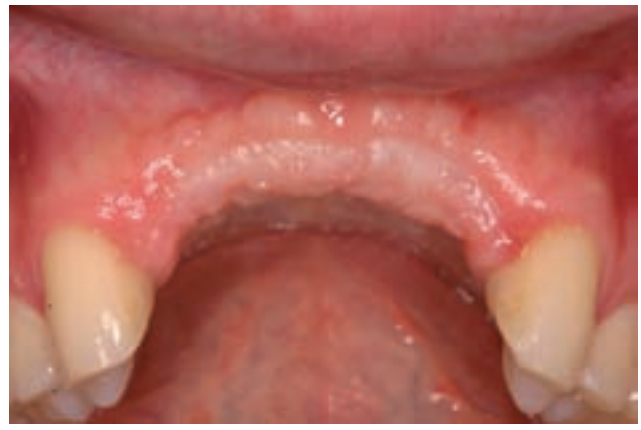


Fig. 13.40 An epithelial–connective tissue graft from the palate was used to repair the soft tissue 8 weeks before bone grafting.

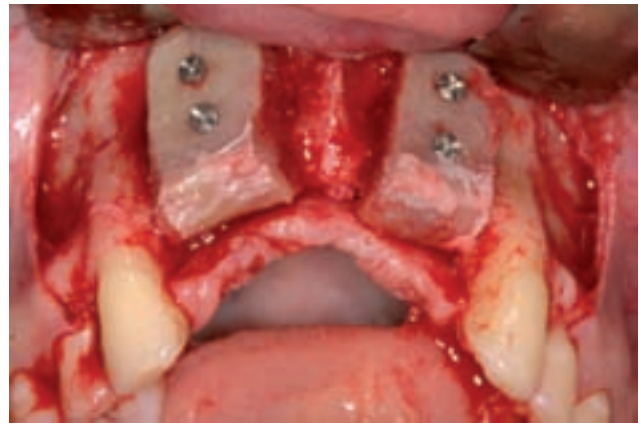


Fig. 13.41 Corticocancellous block bone grafts from the ilium are used to reconstruct the defect.

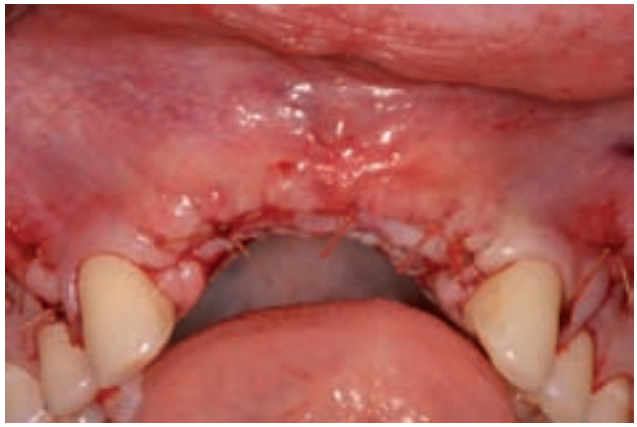


Fig. 13.42 The improved soft-tissue character allows primary closure over the graft.

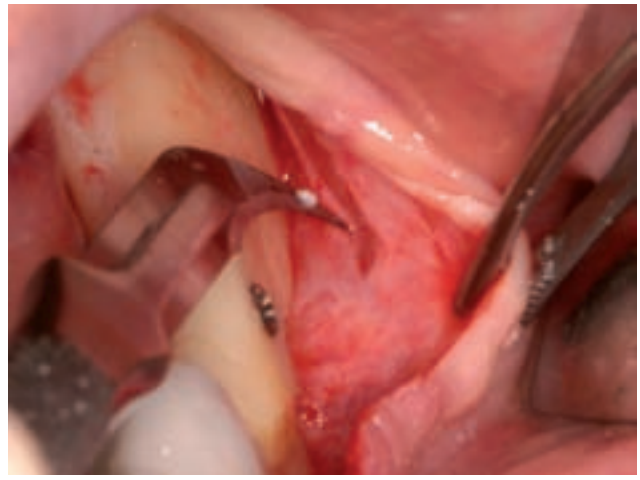


Fig. 13.43 The periosteum along the buccal flap is incised with a no. 12 blade to release tension.

allogeneic tissue may be considered as an alternative source. Soft-tissue corrective surgery should be performed at least 8 weeks before bone graft surgery to allow incorporation of grafted tissue and re-establishment of vascularity to the area.

The bone defect and graft recipient site are usually exposed and prepared before bone graft harvest. This allows a better determination of the needs for bone repair and minimizes the length of time from bone harvest to graft placement. An understanding of vascular patterns within the oral cavity is important to prevent vascular compromise and poor healing. Incisions to expose the recipient site are typically made along the ridge crest. Crestal incisions maintain vascular supply to the flaps as vessels facial to the ridge do not cross over to the palatal or lingual regions (56). Incisions made significantly palatal to the ridge in the maxilla and buccal to the ridge in the posterior mandible can result in wound breakdown from necrosis. Divergent releasing incisions remote to the defect produce a broad-based flap that facilitates closure and also maintains blood supply (Fig. 13.41). It is preferred to make the primary crestal incision through keratinized mucosa. If there had been a loss of keratinized mucosa then free gingival grafting may be performed to enhance the quality of the tissue.

Several steps are taken to advance the soft-tissue flap over an onlay bone graft. The mucoperiosteal flap reflection should extend well beyond the localized area of bone repair. Secondary vertical releasing incisions also improve flap mobility. The greatest limitation to flap advancement over the bone graft is due to the periosteum. A horizontal incision is made through the thin periosteal layer along the base of the facial flap. The periosteal incision should extend along the entire base of the flap and connect to the vertical releasing incisions. It is important that the periosteal incision remains superficial, avoiding deeper vessels feeding the flap and nerve

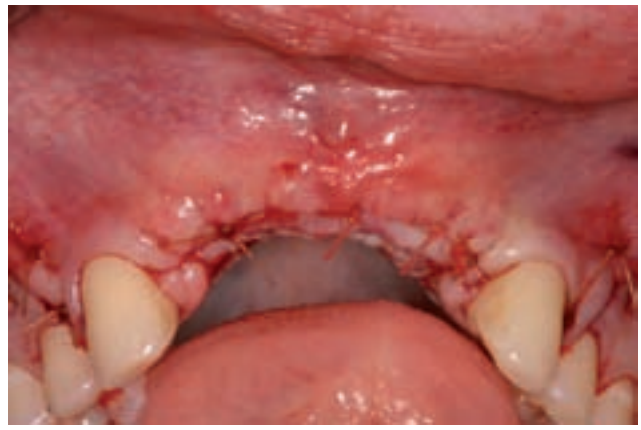


Fig. 13.44 The flap is closed primary with 4-0 Vicryl mattress and interrupted sutures.

branches within the region (i.e. infraorbital and mental nerves) (Figs 13.43, 13.44). After the periosteal releasing incision is made the flap is gently stretched to assess closure without tension. If resistance to adapting the wound margins is noted then further flap release can be obtained with blunt dissection through the periosteal release and beyond the vestibular depth (57). Blunt scissors or a hemostat can be advanced through a plane parallel to the facial bone. This will avoid compromising the blood supply to the flap. In the maxilla the palatal tissue is more difficult to mobilize so the majority of tissue coverage comes from the facial flap. A palatal incision made parallel and remote from the ridge crest can provide some palatal flap mobility if needed. Lingual flap advancement can be obtained in the posterior mandible by reflecting the mucoperiosteal flap to the mylohyoid muscle attachment and using a finger to stretch and release the thin periosteum (Fig. 13.45). Scar tissue, from previous infections or failed surgical procedures, can also cause resistance to adaptation of the

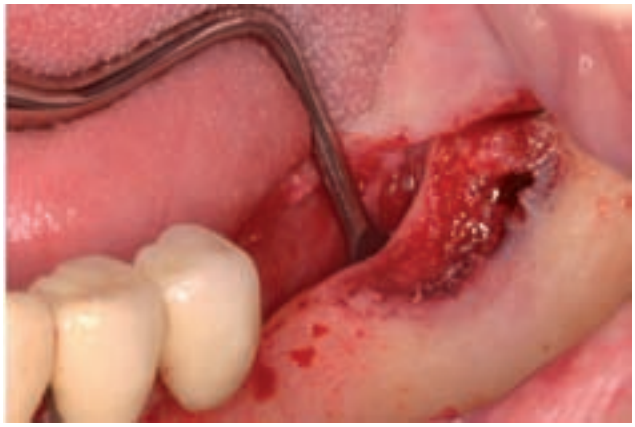


Fig. 13.45 A Miller curette is used to reflect the lingual flap in the posterior mandible.

wound margins. In addition, scar tissue compromises blood supply and healing of the flaps. For this reason the retreatment of failed augmentation cases is more complicated and should be managed by more experienced surgeons.

Procedures to enhance graft coverage will usually result in a loss of vestibular depth. This is rarely a problem with an implant-retained restoration as the prosthesis does not require a soft-tissue seal for retention. The advancement of the facial flap over the graft may often reposition the keratinized gingiva more palatally or lingually. In some cases soft-tissue grafting may be necessary but the keratinized tissue can usually be moved facially during second stage uncovering of the implants. Although it is important that the flap margins are well approximated, the sutures should not be pulled too tightly or ischemia will occur. The flaps should be closed over the bone graft with suture materials that maintain their tensile strength until the wound has completely healed. Vicryl, PTFE, or nylon suture is preferred over materials such as chromic gut or silk. Multiple interrupted or mattress sutures are used to close the flaps over the grafted site. The sutures should be left intact until the incision is healed (10–14 days). The use of steroids can diminish postoperative edema that places additional tension on the flaps. Glucocorticoids, such as dexamethasone, may be administered in a tapering dose over a 3-day period (i.e. 9 mg, 4.5 mg, 3 mg) (58).

The addition of supplemental growth factors has been reported to enhance and accelerate soft-tissue wound healing (2, 59). Platelet-rich plasma has been shown to improve the healing of skin graft donor sites (60). Many clinicians have anecdotally observed the positive effect of autologous growth factors on soft-tissue healing. The various cytokines and mediators found in the alpha granules of the platelets promote angiogenesis and collagen synthesis (61). This may enhance soft-tissue healing and diminish the risk of wound dehiscence and bone graft exposure to the oral cavity. A layer of platelet-rich plasma is placed over the graft site just before suturing the flaps (Figs 13.46–13.49). The development of recombinant human platelet-derived growth factor (rhPDGF) provides another strategy for improving wound healing and preventing complications. This form of the growth factor is estimated to be 1000 times the strength of auto-

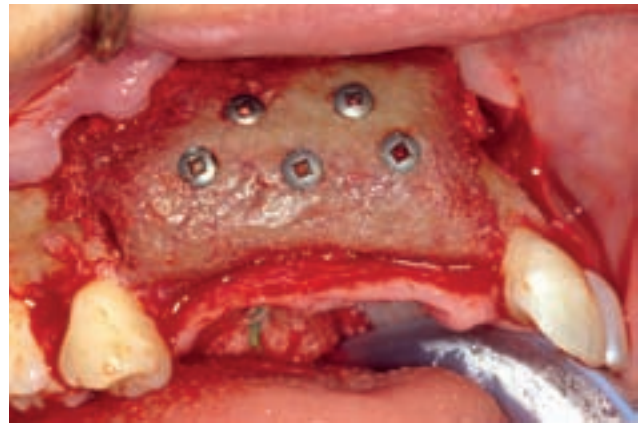


Fig. 13.46 A corticocancellous block bone graft is used to reconstruct the significant maxillary defect.

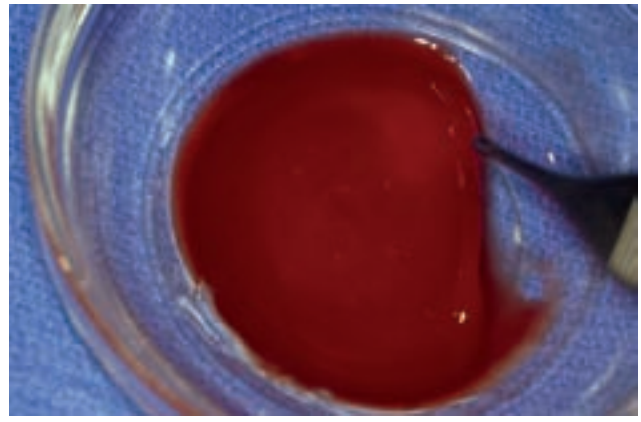


Fig. 13.47 A platelet-rich plasma dressing is prepared before flap closure.

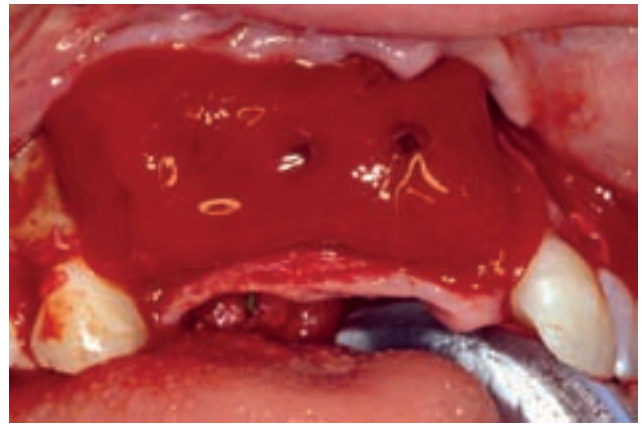


Fig. 13.48 The platelet-rich plasma dressing is placed over the graft before flap closure.

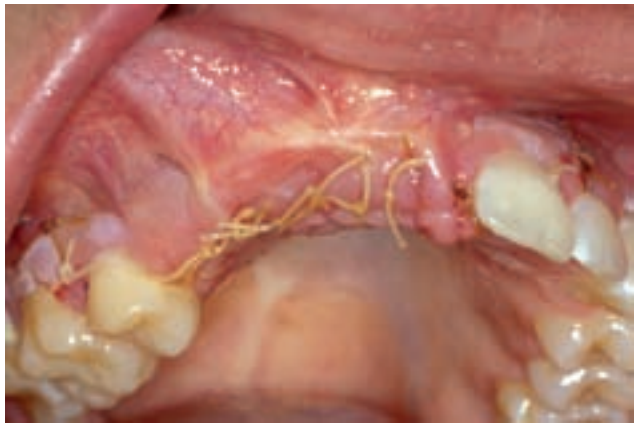


Fig. 13.49 The patient returns 1 week postoperatively and the wound healing is accelerated.

logous platelet-rich plasma and avoids the need for procuring blood for centrifuging. The liquid rhPDGF may be soaked into a thin collagen sponge and placed over the graft site before closure (Figs 13.50–13.52).

If possible, any removable soft-tissue-borne prosthesis should be left out of the mouth as much as possible following surgery until the incision has healed. If it is necessary for the patient to wear their prosthesis it should be modified to protect the early wound healing. The flange should be reduced over the graft area as the vestibular depth is usually reduced from flap closure. The internal surface of the prosthesis should be generously relieved over the graft site. Tissue conditioners may be placed within the denture after suture removal.

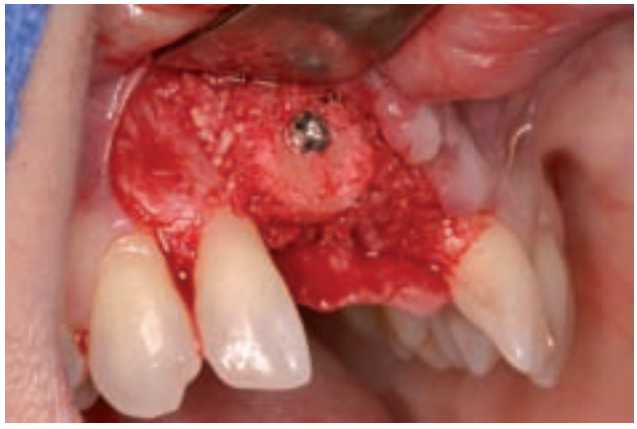


Fig. 13.50 The maxillary defect is reconstructed with a cortical plug from the tibia and cancellous bone.

The postoperative management of wound dehiscence after onlay bone grafting is based on the biologic principle that the graft is non-viable until revascularized. No attempt should be made to resuture or manipulate the surrounding flaps as the edematous soft tissue is inflamed and friable. Once exposed to the oral cavity the microporous surface of the bone graft is contaminated with a biofilm of bacteria. As such, the exposed bone is no longer biocompatible and the surrounding soft tissue will not accept attempts at recovery. In addition, epithelium will not grow over the exposed bone. The clinician should let the wound declare itself and closely monitor the healing (Figs 13.53, 13.54). The patient should continue to keep the area clean with chlorhexidine rinses twice daily and salt water rinsing after meals. Smoking will delay healing and lead to greater graft exposure. Beyond the initial 1-week prescription, further antibiotic coverage is not required unless infection develops (swelling, erythema, exudate). Periodic local application of tetracycline paste has been used but the benefit of this practice is undetermined. Sharp protruding edges of the bone graft may be smoothed and reduced with a coarse diamond bur. If more than half of the bone graft becomes exposed the prognosis is poor and graft removal should be considered. Cancellous bone grafts tolerate exposure better than cortical bone grafts as they revascularize more quickly (62) (Fig. 13.55).

When premature bone graft exposure occurs the patient should be seen on a weekly basis to check for infection or sequestering of the graft. Periapical radio-

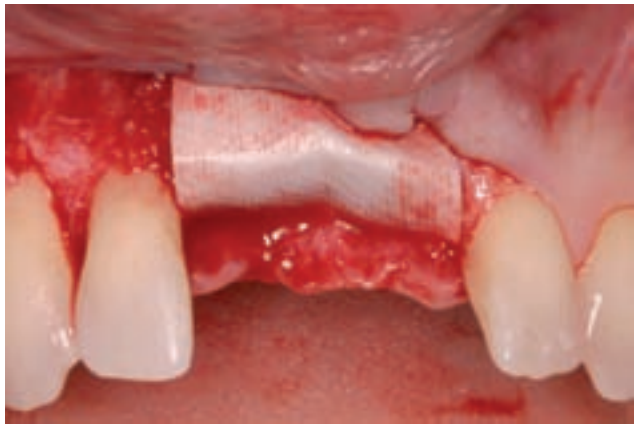


Fig. 13.51 The grafted site is covered with a collagen membrane soaked in recombinant human platelet-derived growth factor.

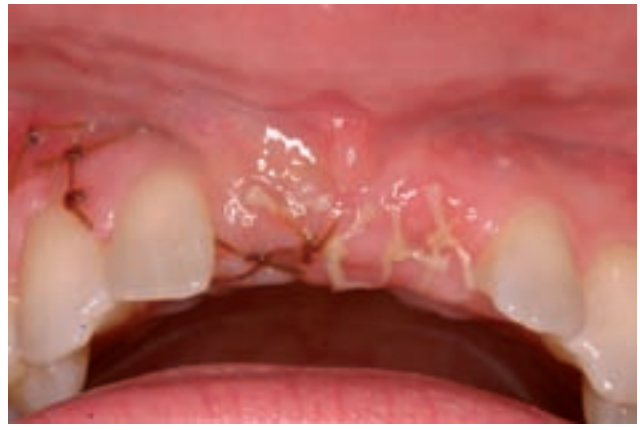


Fig. 13.52 A postoperative view 1 week later reveals excellent soft-tissue healing over the graft.

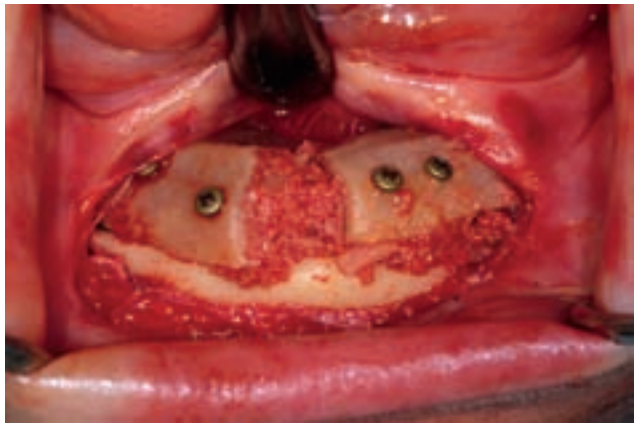


Fig. 13.53 A corticocancellous bone graft used to reconstruct the severely atrophic mandible.

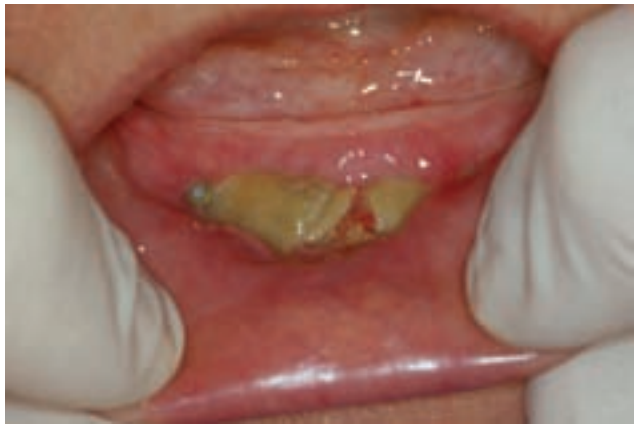


Fig. 13.54 Wound dehiscence of the flaps exposes the bone graft.

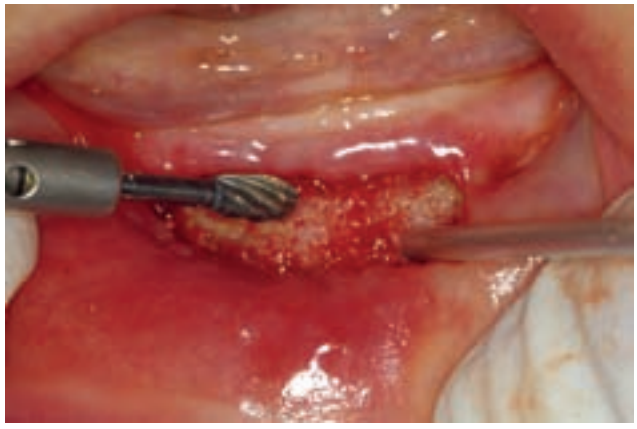


Fig. 13.55 Four months postoperatively a carbide bur is used to remove necrotic bone and expose bleeding bone.

graphs are taken of the graft site monthly to check for graft resorption or non-union (radiolucent space). If the exposed bone graft is stable after 2 months the incorporating of the graft can be tested. If a fixation screw head is visible the screw is unthreaded and the graft is checked for stability (Fig. 13.56). If the graft is mobile the prognosis for incorporation is questionable and removal should be considered. If the graft is stable then the screw is reinserted and the graft is monitored for another 2 months. Following a 4-month healing period the graft is completely inspected and evaluated. The exposed superficial necrotic bone should be removed with a bur. Bleeding from the underlying bone is a positive sign of graft incorporation. Implants may be inserted at this time or the clinician can wait for an additional 2 months to let further remodeling occur.

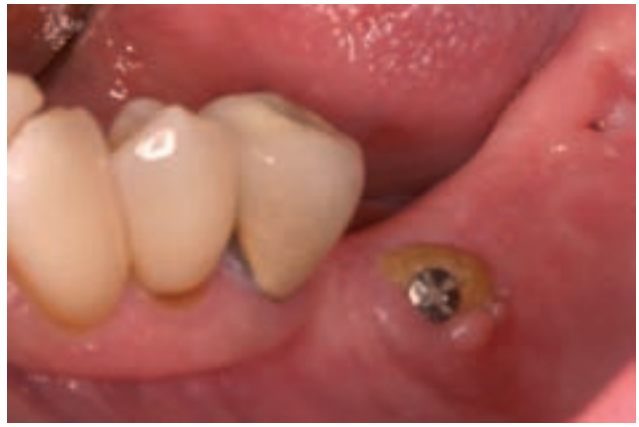


Fig. 13.56 Postoperative smoking caused graft dehiscence, exposing the screw.

- *Complication*: wound dehiscence over bone graft.
- *Etiology*: clinician inexperience, poor tissue quality/quantity, extraction defect, lack of tension-free closure, swelling, smoking, prosthesis irritation.
- *Prevention*: case selection, soft-tissue grafting, staged extractions, broad flap reflection, periosteal release of the flap, smoking cessation, growth factors, stable suture material, glucocorticoids, fixed provisional prosthesis or disuse and modification of removable prosthesis.
- *Treatment*: monitoring, chlorhexidine rinse, antibiotics for infection, debulking exposed graft, radiographs, screw test, necrotic graft removal.

Infection

The incidence of postoperative infection after onlay bone graft surgery is low (63, 64). Infections may occur within the graft donor or recipient site. Although clean technique has been found acceptable for dental implant surgery (65), clinicians should consider using aseptic technique during more extensive and prolonged reconstructive procedures. When extraoral donor sites are used (tibia, ilium) strict sterile technique is used. The skin is prepped with antiseptic solution and the surgical field is isolated with sterile drapes.

As the consequences of postoperative infection are detrimental to graft success, the patient should be placed

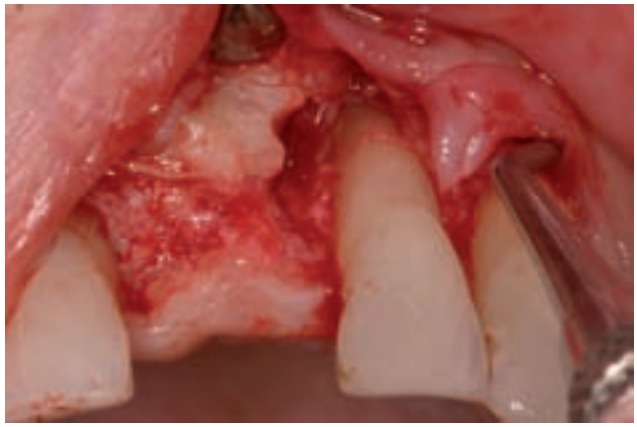


Fig. 13.57 A late infection of the bone graft related to the lateral incisor.

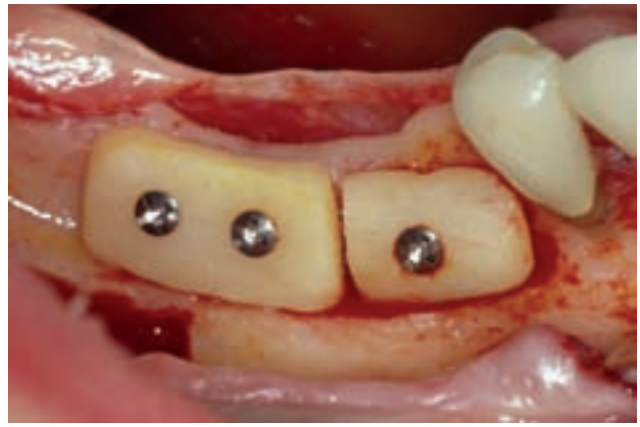


Fig. 13.58 A cortical bone graft used to reconstruct the atrophic posterior mandible.

on prophylactic antibiotics starting with a loading dose 1 hour before surgery and continuing for 1 week (23, 63). Amoxicillin is commonly used as it is well absorbed and only requires administration three times a day. Penicillin-allergic patients may be treated with a cephalosporin, clindamycin, or clarithromycin. Preoperative chlorhexidine rinsing can reduce the bacterial contamination of intraorally harvested bone grafts (66). Chlorhexidine rinse is used thereafter twice daily following surgery as oral hygiene procedures, such as brushing and flossing, are avoided around the surgical site. Antisialologue agents, such as glycopyrrolate, may be administered preoperatively to decrease salivary flow that may carry bacteria into the grafted site. As expected, wound dehiscence is associated with a higher incidence of postoperative infection of the graft recipient site (67). Postoperative infections of the graft site are treated aggressively. As the patient is often already taking a postoperative antibiotic the use of another drug with expanded coverage is selected for combination therapy (i.e. amoxicillin plus metronidizole). Late infections are far less common and are usually associated with graft dehiscence or graft sequestration (Fig. 13.57).

- *Complication*: graft infection.
- *Etiology*: bacterial contamination, wound dehiscence.
- *Prevention*: aseptic technique, prophylactic antibiotics, chlorhexidine rinse, antisialologue.
- *Treatment*: antibiotics.

Recipient site complications: late healing complications

Bone graft incorporation and resorption

The use of autogenous bone for ridge augmentation has been the center of some controversy. Historically, autogenous bone grafts, harvested from the ilium and rib, were used in preprosthetic surgery for the reconstruction of the atrophic maxilla and mandible before the fabrication of complete dentures. The lack of stimulation of the graft and pressure from the prosthesis caused loss of the majority of the graft in a short period (68). The unfavorable outcomes of autogenous bone under these conditions led many clinicians to believe resorption would also occur in augmentation for implant placement.

Graft resorption is a necessary aspect of graft incorporation to the osseous recipient site. The cortical portion of the autogenous bone graft acts as an osteoconductive scaffold for bone formation (69). The bone graft is remodeled and replaced with new bone over time (creeping substitution) (69). Bone cells, in higher concentration in the cancellous marrow, surviving the transplantation produce osteoid (69). Free autogenous bone grafts must become revascularized in order to incorporate. The cancellous portion of the graft revascularizes more rapidly than the cortex (70). The denser cortical bone revascularizes through its existing haversian system (70).

The embryologic origin of an autologous bone graft has been suggested as a predictor of graft resorption. Membranous bone grafts, from the mandible or calvarium, have been found to reveal less resorption than grafts from endochondral sites, such as the iliac crest (71–75). More recent studies emphasize the importance of the microarchitecture of the bone used for grafting over embryologic origin (69, 76). Denser cortical bone grafts resorb less than more porous cancellous bone grafts when used for onlay bone augmentation (76). Cortical bone grafts from the mandible exhibit minimal resorption and maintain their dense quality, making them ideal for onlay augmentation before implant placement (23) (Figs 13.58, 13.59). Upon incorporation the volume loss of cortical bone grafts used for onlay augmentation is less than 20% (77). Corticocancellous bone grafts from the ilium are associated with greater resorption owing to the thinner outer cortex and more porous cancellous compo-

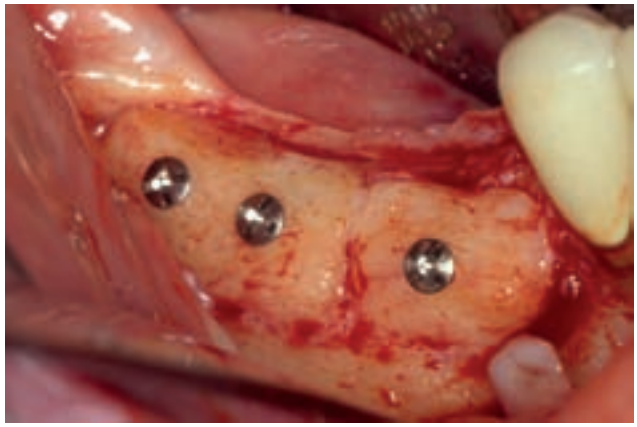


Fig. 13.59 Excellent incorporation of the graft 4 months later with minimal resorption.

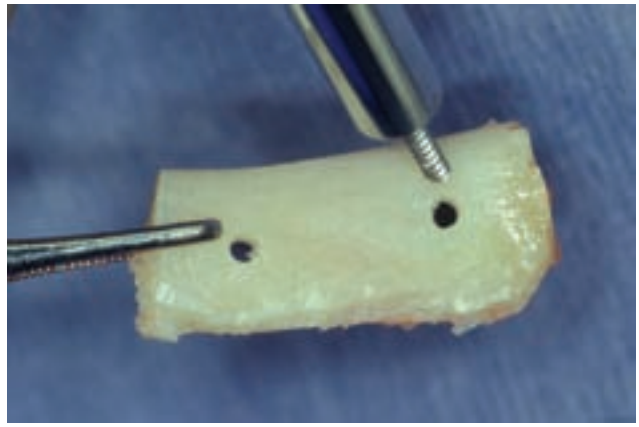


Fig. 13.61 The cortical bone graft is fixated using a lag screw technique.

nent. Whereas the greatest change in the width of a corticocancellous graft occurs in the first 3 months the volume loss in height stabilizes after 1 year (78). It is prudent to overbuild the reconstructed ridge slightly, in anticipation of some volume loss upon healing.

The osseous recipient bed is prepared to improve the fit and contact of the bone block graft. Perforation of the cortex in the recipient site with a small round bur releases growth factors, expedites revascularization of the graft, and improves the graft incorporation (79) (Fig. 13.60). Decortication of the recipient site to improve graft fit is preferred over significantly adjusting the block graft (79). Corticocancellous block grafts require less adjustment as the softer cancellous bone will often mold to the ridge.

Block bone grafts do not tolerate micromovement and will resorb unless rigidly fixated. The graft is mortised into the recipient bed and fixated to the ridge with screws. Fixation screws typically range from 1 to 2 mm in diameter. A screw length that maximizes retention within the native bone should be selected. A lag screw technique is used for fixation of cortical onlay bone grafts (Fig. 13.61). The screw engages and threads the host bone but fits passively through the block bone graft to compress and rigidly fixate the graft. Although one screw may be considered for small block grafts, repairing single tooth sites, two or more screws should be used for larger grafts. The fixation screws may also have a positive effect on graft retention as they tent the periosteum during remodeling. When the grafted site is re-entered for implant placement the flap exposure should be minimized to maintain blood supply to the graft. The fixation screws may be removed through small stab incisions made over the screw head rather than reflecting a large flap (Figs 13.62, 13.63).

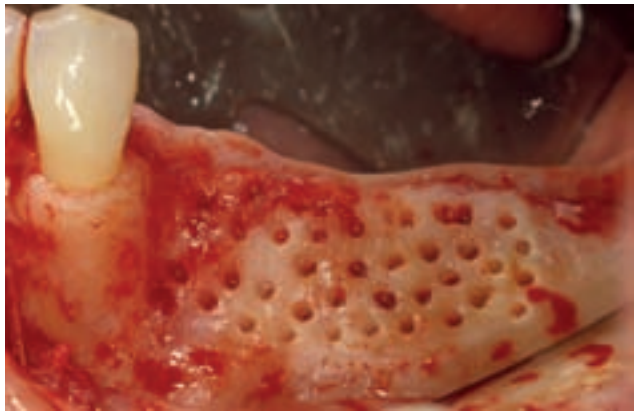


Fig. 13.60 The cortex in the recipient site is perforated with a bur to improve graft incorporation.

The use of a barrier membrane has been suggested as a strategy to reduce resorption of block bone grafts. Although some studies have found that membranes have a positive influence on graft loss, others dispute the benefit of this practice (80). Although a membrane can reduce graft loss initially, it may simply delay bone resorption until after it is removed or resorbed (81). In addition, membranes increase costs and can contribute to complications. Cortical bone grafts exhibit minimal resorption and do not typically require membrane protection (23, 76, 77, 82). Although the routine use of membranes over block onlay bone grafts is questionable a barrier membrane may improve the incorporation of the peripheral particulate graft around the block (83). When a block bone graft does not completely reconstruct the ridge deficiency particulate bone can be placed around the block and covered with a barrier membrane (Figs 13.64–13.67). Autogenous bone chips or particulate bone substitutes, such as mineralized bone allograft or bovine-derived hydroxyapatite, may be considered for this purpose. Membranes should always be used with particulate or cancellous grafts for onlay ridge augmentation as they are more susceptible to volume loss. Collagen membranes are preferred as they are associated with fewer complications than polytetrafluoroethylene (PTFE) membranes, such as exposure and infection (84).

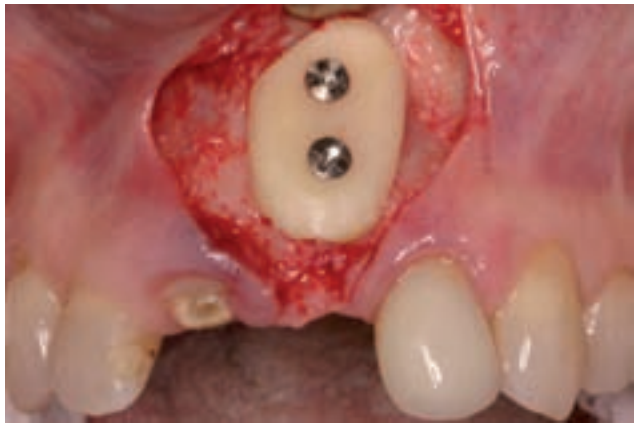


Fig. 13.62 The maxillary anterior defect is repaired with a cortical bone graft.

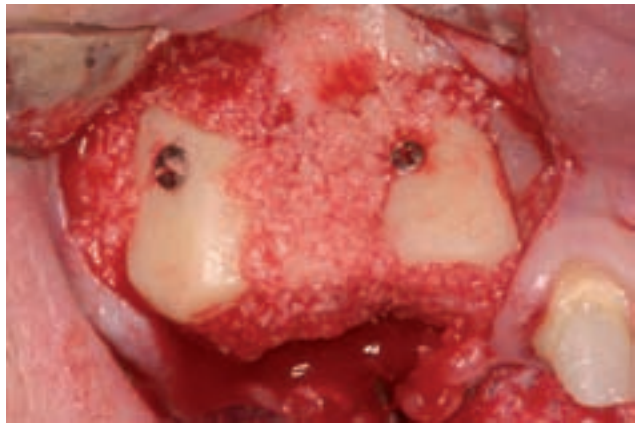


Fig. 13.65 Particulate bone is packed around the periphery of the block grafts.

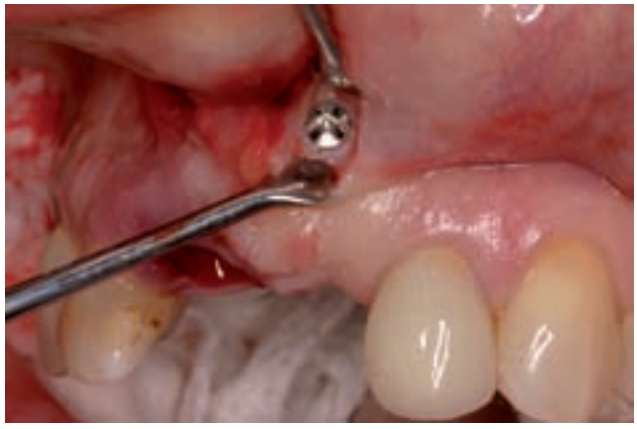


Fig. 13.63 Four months postoperatively the fixation screw is removed through a small mucosal incision.

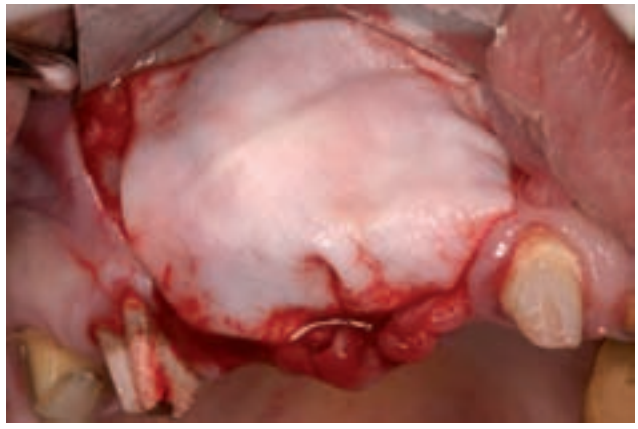


Fig. 13.66 A collagen membrane is used to cover the grafted site.

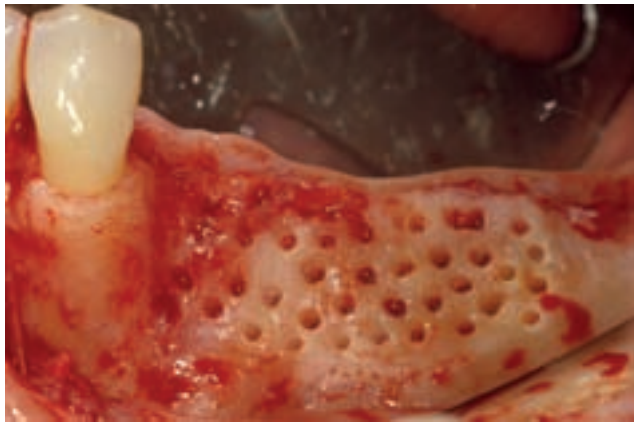


Fig. 13.64 The maxillary right defect is reconstructed with cortical bone grafts.

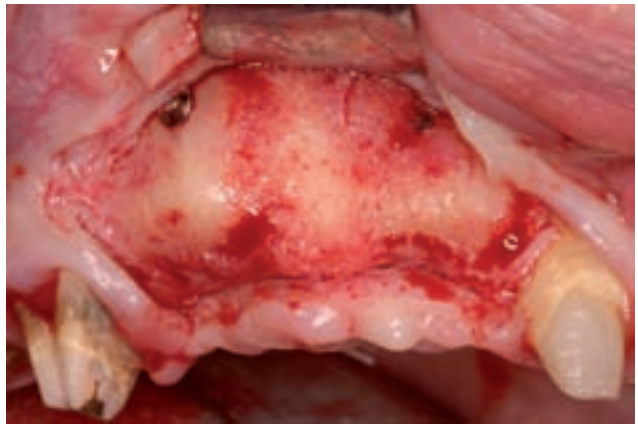


Fig. 13.67 The particulate bone is well incorporated around the block bone grafts with minimal resorption.

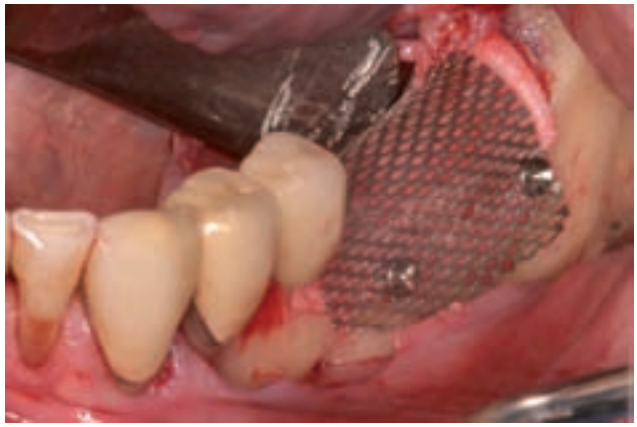


Fig. 13.68 Titanium mesh is used to maintain space and protect the particulate bone graft during healing.

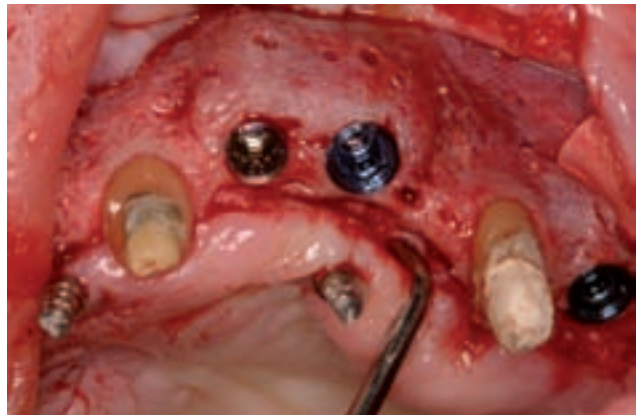


Fig. 13.70 The bone graft has been protected and exhibits excellent incorporation for implant placement.

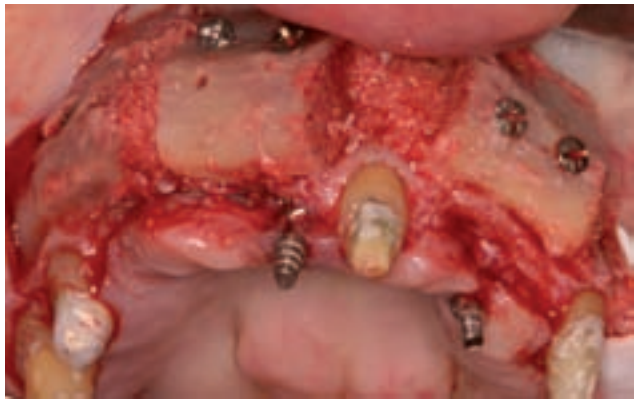


Fig. 13.69 Provisional implants are placed into the native bone palatal to the bone grafts to support a temporary bridge.

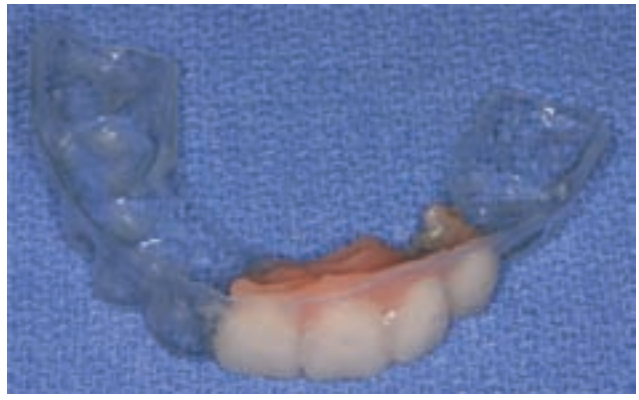


Fig. 13.71 An Essix retainer is used as a provisional tooth replacement over the graft site.

Another approach for particulate cancellous bone is to use titanium mesh to support and protect the graft during healing (85, 86) (Fig. 13.68). Grafts with a larger cancellous component and particulate grafts are more susceptible to volume loss. When using corticocancellous block grafts, compaction of the cancellous bone with an instrument can help minimize overall volume loss during healing.

It is imperative that the onlay bone graft remains immobilized during healing. A fixed provisional prosthesis, such as a temporary bridge or bonded prosthesis, is preferred for tooth replacement over the grafted site. Transitional implants have been used successfully to support fixed interim prostheses for patients less tolerant of complete or partial dentures (87). The transitional implants should be placed in native bone and not within the bone graft (Figs 13.69, 13.70). A removable Essix retainer is an excellent option for cosmetic tooth replacement during graft healing as it does not place any pressure on the site (Fig. 13.71). As previously noted, the use of a soft-tissue-borne removable prosthesis is discouraged for the first few weeks until the incision has healed. Removable prostheses should then be adjusted to minimize any contact with the grafted site. Metal base removable partial dentures, with rest seats on the abutment teeth, are preferred over acrylic soft-tissue-borne prostheses as there is less potential for loading of the graft under function (Figs 13.72, 13.73). However, the major connector should be designed so there is no metal frame-

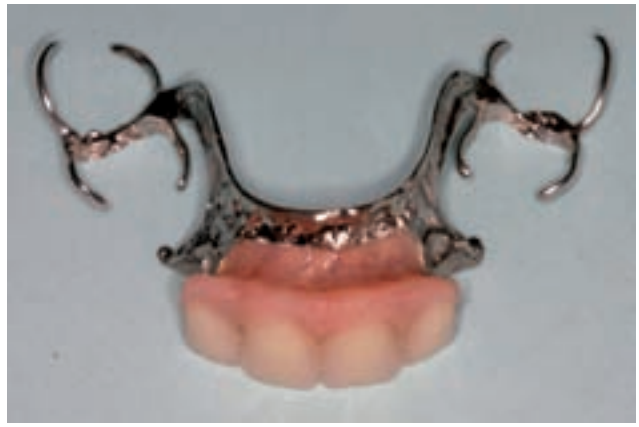


Fig. 13.72 A metal base removable partial denture is constructed with no metal over the graft site.

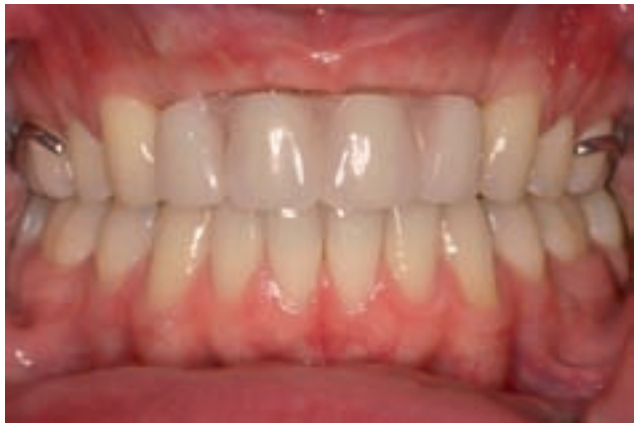


Fig. 13.73 The removable partial denture is adjusted over the graft site. (Patient from Figs 13.39–13.42.)

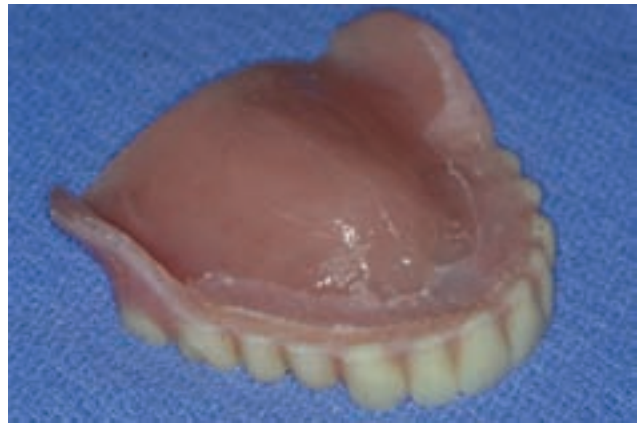


Fig. 13.74 The flange of the complete denture is completely removed in the grafted areas and relieved over the ridge.

work over the graft site. For patients wearing a complete denture the flange should be removed over the graft area. The internal surface of the prosthesis should also be generously relieved over the graft site. The denture may be relined with tissue conditioner after suture removal (Figs 13.74, 13.75). The patient is instructed to use their removable prosthesis for cosmetic appearance and minimize function. Unfavorable concentration of forces from the opposing dentition should be avoided and a broad distribution of occlusal contacts is preferred (88). Bruxism has been found to impact outcomes negatively in grafted patients (67). Patients wearing removable prostheses over larger bone grafts should maintain a softer diet for at least 2 months after surgery. After this period the onlay graft will have formed a union to the host bone and will rely less on the fixation screws for immobility.

- *Complication*: graft resorption.
- *Etiology*: graft remodeling, graft character (cortical, cancellous), poor fixation, graft loading.
- *Prevention*: recipient site preparation, fixation screws, barrier membrane, overbuild graft site, fixed provisional prosthesis or disuse and modification of removable prosthesis, minimize re-entry flap reflection.
- *Treatment*: shorter implants, narrower implants, regraft at implant insertion.

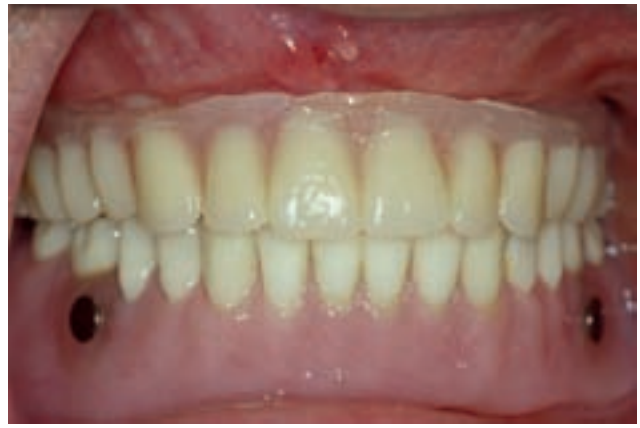


Fig. 13.75 Tissue conditioner is used to fill the space over the ridge.

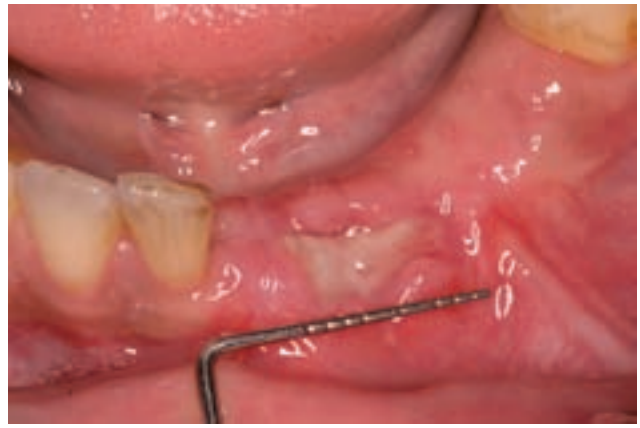


Fig. 13.76 Poor wound healing over the bone graft in this smoking patient.

Patient habits/systemic disease

Smoking

Smoking has been associated with a high rate of wound dehiscence and onlay bone graft failure (67, 89, 90) (Fig. 13.76). Smoking patients are poor candidates for onlay bone grafting and unless they will consider smoking cessation a clinician should not perform graft surgery. The use of chewing tobacco is also discouraged after bone graft surgery. Although smoking has negative systemic influences on wound healing, the local oral effects may be more detrimental. As such, a smoking cessation protocol has been developed to allow unimpeded soft-tissue healing over the graft. Smoking patients should be thoroughly educated regarding the higher risk of com-

plications and this should be clearly documented as part of their informed consent. The patient is given a specific "quit date" to stop smoking completely. This is ideally 2–4 weeks before surgery but may be as close as 1 week from the appointment. Heavy smokers (one to two packs per day) may be a higher risk for non-compliance and may be allowed to stop on the day of surgery. The patient is started on a prescription for bupropoin (Zyban) or varenicline (Chantix) at least 1 week before surgery. In addition, they are instructed to begin use of a nicotine transdermal patch (if they have also quit smoking). Smoking cessation has been found to be more successful with a combination of bupropin and the nicotine patch than either agent used alone (91). However, the patient's blood pressure should be closely monitored with these combined agents as increased hypertension has been noted. Patients are instructed not to smoke at least until the incision is completely closed. This time period may be hastened with the use of growth factors (such as rhPDGF). The postoperative course of these patients should be closely monitored with positive reinforcement of the protocol. If the patient returns to their smoking habit after the soft tissue has covered the bone graft successful incorporation may still occur. However, smoking has also been reported as an important risk factor in dental implant failure (92, 93).

Bisphosphonate therapy

The risk for developing bisphosphonate-associated osteonecrosis of the jaw is significant for cancer patients on intravenous bisphosphonate therapy. Invasive dental procedures, such as elective bone grafting, should be avoided in patients receiving intravenous bisphosphonates. Although cases have been reported, the risk of developing osteonecrosis following oral surgical procedures for patients taking oral bisphosphonate medications appears extremely low (94). Several studies have found no incidence of bisphosphonate-related osteonecrosis in association with dental implant surgery (95–98). There is a paucity of literature on the possible negative effects of oral bisphosphonates on alveolar bone grafting procedures. One recent retrospective study found that patients taking oral bisphosphonates were at no greater risk of dental implant or bone graft failure (98). The author has not observed bone graft complications with numerous postmenopausal females on bisphosphonate therapy. On the contrary, the use of bisphosphonate therapy is currently under investigation as a strategy to limit bone graft resorption and improve incorporation (99–101). Elective bone grafting surgery does not appear to be contraindicated in this patient population. However, when concomitant risk factors are present, such as prolonged use of oral bisphosphonates (> 3 years), older age (> 65 years) or use of estrogen or glucocorticoids, the clinician may consider additional testing, drug holiday, or alternative treatment options (94, 102). It has been proposed that discontinuation of oral bisphosphonates for a period of 3 months before and 3 months after elective invasive dental surgery may lower the risk of osteonecrosis (102). Modification of oral bisphosphonate therapy should be done in consultation with the patient's physician.

Graft fracture

Reconstruction of the atrophic jaws for implant placement is usually staged with implant placement after graft healing. Previous studies on simultaneous bone graft and implant placement reveal lower success rates, unpredictable bone remodeling and diminished bone-to-implant contact (5, 24, 103, 104). Onlay bone grafts should be allowed to incorporate before dental implant placement. Enough time should elapse for graft incorporation, but implants should be inserted early enough to stimulate and maintain the regenerated bone (78). Autogenous block grafts should heal for approximately 4 months before implant placement (23, 105). Particulate cancellous bone grafts with barrier membranes or titanium mesh used for ridge augmentation often require longer healing periods of at least 6 months. Additional graft resorption after implant placement and delayed loading has not been noted radiographically (78, 106).

The placement of implants into healed bone grafts is similar to their use in sites that have not been grafted. However, the implant site is often at the junction between the block and host bone. The surgeon should be careful not to displace the block from the ridge during the implant osteotomy and placement.

Fixation screws are usually removed before implant insertion. Elevation of large flaps simply for screw removal is discouraged as this disrupts the vascular supply to the healed graft. Small mucosal incisions over the screw heads allows for easy retrieval. If a fixation screw is not in the path of implant insertion it may be left intact, especially if it will provide added stability to the graft (Fig. 13.77). Upon healing, the quality of block mandibular bone grafts is often dense regardless of the original quality of the recipient bone. An appropriate drilling sequence for dense bone and even tapping may be necessary for implant insertion in cortical bone grafts. The use of a side-cutting bur (Linderman bur) is helpful to prepare the osteotomy adjacent to the cortical bone graft before inserting the next wider diameter implant drill (Fig. 13.78). The clinician should be careful when inserting tapered implants or implants with a wider platform at the crest as the graft may fracture under the wedging effect (Figs 13.79, 13.80). When a fracture is noted the clinician may consider inserting a new fixation screw to stabilize the block (Fig. 13.81). If the graft is unstable the

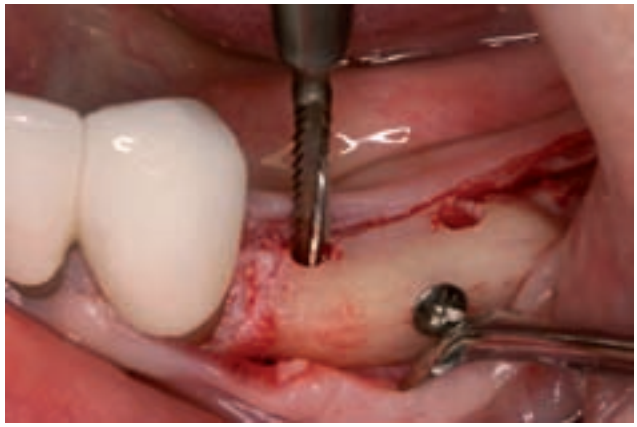


Fig. 13.77 The fixation screw is remote to the implant site. A Linderman bur is used to widen the osteotomy.

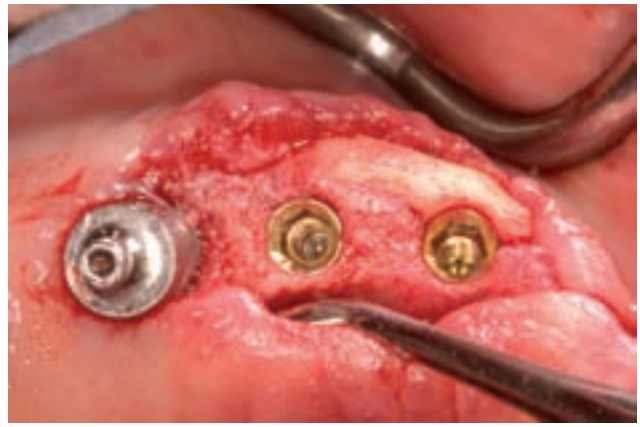


Fig. 13.80 The anterior segment of the cortical graft has fractured from the host bone during implant insertion.

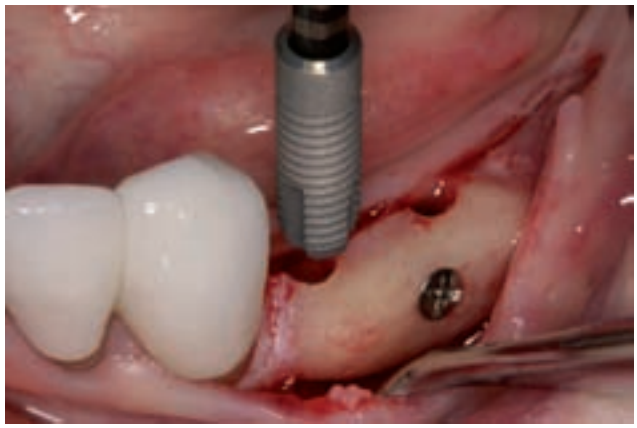


Fig. 13.78 The fixation screw is left intact during implant placement.

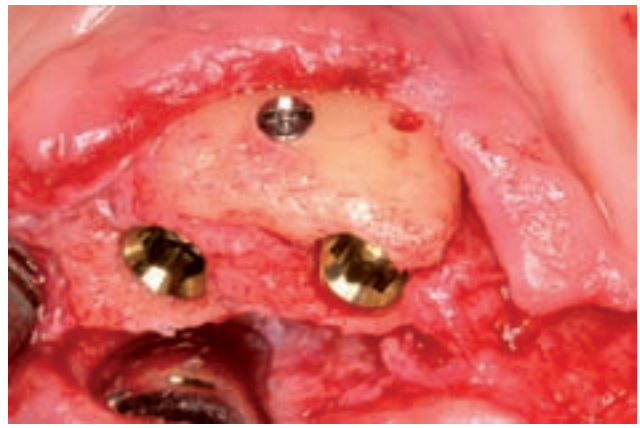


Fig. 13.81 A new fixation screw is inserted to stabilize the bone graft.

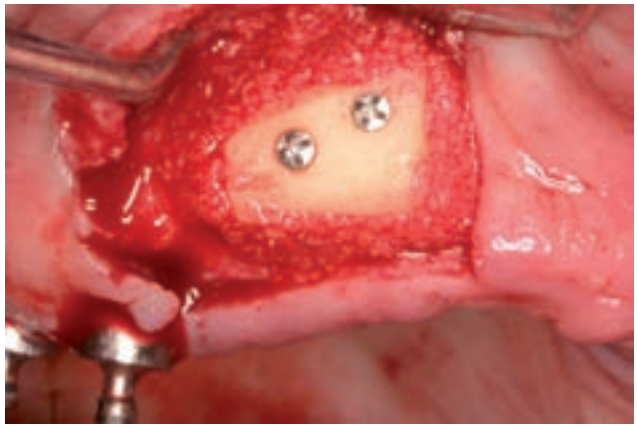


Fig. 13.79 A cortical bone graft is used to augment the atrophic maxilla.

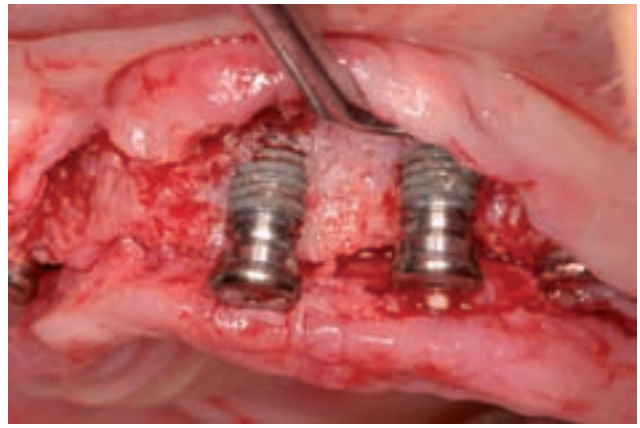


Fig. 13.82 Bone loss around the implants caused by trauma from the soft-tissue-borne prosthesis.

implant(s) should not be inserted. The implant osteotomy can be filled with particulate bone and the site may be re-entered after 2–4 additional months.

- *Complication*: graft fracture.
- *Etiology*: poor graft union, drilling sequence, countersunk implant.
- *Prevention*: fixation screw, Linderman bur, screw tap, parallel implant.
- *Treatment*: implant unthreading, screw refixation.

Implant failure

The healing period of implants placed in a staged manner into incorporated bone grafts is similar to native bone. Implants placed in grafted sites with favorable bone quality may be uncovered and/or restored earlier. Immediate implant loading in grafted bone may even be considered if primary implant stability is adequate. Microtextured implant surfaces have diminished healing implant periods to as little as 6–8 weeks (107). A longer implant healing period and submerged healing are advised in compromised bone quality. Implant survival in grafted sites may be a function of residual bone supporting the implant rather than grafted bone (3). In early studies implant survival rates in reconstructed ridges were often lower than those reported in native bone (5, 103). Compromised results can largely be attributed to the use of machined implants in softer corticocancellous bone grafts, simultaneous graft-implant placement and developmental techniques. A recent systematic review of the literature on implants in onlay bone grafts found a survival rate of 90.4% (3). However, a limited number of publications met the review's inclusion criteria and the studies included machined surface implants and simultaneous graft-implant placement. Higher implant failure rates in onlay grafted sites have been noted in association with more advanced atrophy, shorter implants, advanced age, bruxism, smoking, and interim removable prostheses (67, 88) (Fig. 13.82). When onlay bone grafts are allowed to heal in a staged approach, contemporary implant survival rates can approach those in native bone sites (83, 86, 108–111). However, bone augmentation procedures can fail and implants placed in these areas do not necessarily enjoy the high long-term survival rates of dental implants placed in pristine sites (112, 113). There are limited publications on the long-term stability of implants in grafted sites and further research is needed to evaluate the performance of implants in augmented bone (106).

- *Complication*: implant failure.
- *Etiology*: simultaneous graft-implant placement, machined surface implants, poor implant stability, poor bone quality/quantity.
- *Prevention*: stage graft and implant placement, use microtextured implants, longer implants, add additional implants when poor bone encountered.
- *Treatment*: replace failed implant(s).

Take-home hints

- Complications can be avoided by exercising good judgment and having a thorough knowledge of anatomy. Proper donor site selection, execution of the surgical techniques, and close follow-up will provide successful outcomes.
- Onlay bone grafting is a technique-sensitive procedure and complications are more common earlier on the learning curve. Clinicians should select cases based on their experience and skill level
- Selection of a graft donor site that provides adequate bone volume for implant placement in ideal locations for prosthetic support is an important aspect of the diagnostic evaluation.
- The choice of intraoral donor sites (symphysis, ramus, tuberosity) should be based on graft size requirements and proximity of the donor and recipient site.
- The bone graft should always be handled over a sterile field with a clamp to prevent accidental contamination.
- It is preferred to correct soft-tissue problems before bone grafting surgery.
- The most common recipient site complication with onlay bone augmentation is incision line opening. All possible precautions should be taken to prevent this devastating complication from occurring.
- Tension-free, primary flap closure over a bone graft may be achieved in most cases by using a broad based flap, divergent releasing incisions, extended mucoperiosteal reflection and periosteal incision.
- Graft resorption is necessary for incorporation. It is prudent to overbuild the reconstructed ridge slightly in anticipation of some volume loss upon healing.
- Block bone grafts do not tolerate micromovement. The block must be well fixated and provisional tooth replacement should avoid contact over the site.
- Decortication of the recipient site and mortising the block graft for an intimate fit will improve graft revascularization and incorporation.
- Smoking patients are poor candidates for onlay bone grafting and unless they will consider smoking cessation a clinician should not perform graft surgery.

References

1. Brånemark P-I, Lindstrom J, Hallen O. Reconstruction of the defective mandible. *Scand J Plast Reconstr Surg* 1975; **9**: 116–28.
2. Misch CM. Autogenous bone grafting for dental implants. In: Fonseca RJ, Turvery TA, Marciani RD, eds. Oral and maxillofacial surgery, Vol. 1, 2nd edn. Philadelphia, PA: WB Saunders Co., 2008: 344–70.
3. Aghaloo TL, Moy PK. Which hard tissue augmentation techniques are the most successful in furnishing bony support for implant placement? *Int J Oral Maxillofac Implants* 2007; **22** (Suppl): 49–70.
4. Jingjing L. Wang H-L. Common implant-related advanced bone grafting complications: classification, etiology and management. *Implant Dent* 2008; **17**: 389–97.
5. Breine U, Brånemark PI. Reconstruction of alveolar jaw bone. An experimental and clinical study of immediate and preformed autologous bone grafts in combination with osseointegrated implants. *Scand J Plast Reconstr Surg* 1980; **14**: 23–48.
6. Mecall RA, Rosenfeld AL. Influence of residual ridge resorption patterns on fixture placement and tooth position, Part III: Presurgical assessment of ridge augmentation requirements. *Int J Periodontics Restorative Dent* 1996; **16**: 322–37.
7. Misch CM. Use of a surgical template for autologous bone grafting of alveolar defects. *J Prosthodont* 1999; **8**: 47–52. 1999
8. Rosenfeld AL, Mecall RA. The use of interactive computed tomography to predict the esthetic and functional demands of implant-supported prostheses. *Compend Contin Educ Dent* 1996; **17**: 1125–8.
9. Nkenke E, Weisbach V, Winckler E, Kessler P. Morbidity of harvesting of bone grafts for the iliac crest for preprosthetic augmentation procedures: a prospective study. *Int J Oral Maxillofac Surg* 2004; **33**: 157–63.
10. Cricchio G, Lundgren S. Donor site morbidity in two different approaches to anterior iliac crest bone harvesting. *Clin Implant Dent Relat Res* 2003; **5**: 161–9.
11. Hahn M, Dover MS, Whear NM, Moule I. Local bupivacaine infusion following bone graft harvest from the iliac crest. *Int J Oral Maxillofac* Surg 1996; **25**: 400–1.
12. Kalk WW, Raghoebar GM, Jansma J, Boering G. Morbidity from iliac crest bone harvesting. *J Oral Maxillofac Surg* 1996; **54**: 1424–9.
13. Schnee CL, Freese A, Weil RJ, Marcotte PJ. Analysis of harvest morbidity and radiographic outcome using autograft for anterior cervical fusion. *Spine* 1997; **22**: 2222–7.
14. Kurz LW, Garfin SR, Booth RE. Harvesting autogenous iliac bone grafts: a review of complications and techniques. *Spine* 1989; **14**: 1324–31.
15. Murata Y, Takahashi K, Yamagata M. Injury to the lateral femoral cutaneous nerve during harvest of iliac bone graft, with reference to the size of the graft. *J Bone Joint Surg Br* 2002; **84-B**: 798–801.
16. O'Keefe RM, Reimer BL, Butterfield LS. Harvesting of autogenous cancellous bone graft from the proximal tibial metaphysic: a review of 230 cases. *J Orthop Trauma* 1991; **5**: 469–74.
17. Catone GA, Reimer LB, McNeir D. Tibial autogenous cancellous bone as an alternative donor site in maxillofacial surgery: a preliminary report. *J Oral Maxillofac Surg* 1992; **50**: 1258–63.
18. Mazock JB, Schow SR, Triplett RG. Proximal tibia bone harvest: review of technique, complications, and use in maxillofacial surgery. *Int J Oral Maxillofac Implants* 2004; **19**: 586–93.
19. Herford AS, King BJ, Audia F, Becktor J. Medial approach for tibial bone graft: anatomic study and clinical technique. *J Oral Maxillofac Surg* 2003; **6**: 358–63.
20. Chen YC, Chen CH, Chen PL, Huang IY, Shen YS, Chen CM. Donor site morbidity after harvesting of proximal tibia bone. *Head Neck* 2006; **28**: 496–500.
21. Thor A, Farzad P, Larsson S. Fracture of the tibia: complication of bone grafting to the anterior maxilla. *Br J Oral Maxillofac Surg* 2006; **44**: 46–8.
22. Sindet-Pedersen S, Enemark H. Reconstruction of alveolar clefts with mandibular or iliac crest bone grafts: a comparative study. *J Oral Maxillofac Surg* 1990; **48**: 554–8.
23. Misch CM, Misch CE, Resnik RR, Ismail YH. Reconstruction of maxillary alveolar defects with mandibular symphysis grafts for dental implants: a preliminary procedural report. *Int J Oral Maxillofac Implants* 1992; **7**: 360–6.
24. Jensen J, Sindet-Petersen S, Oliver AJ. Varying treatment strategies for reconstruction of maxillary atrophy with implants: results in 98 patients. *J Oral Maxillofac Surg* 1994; **52**: 210–16.
25. Lundgren S, Moy P, Johansson C, Nilsson H. Augmentation of the maxillary sinus floor with particulated mandible: a histologic and histomorphometric study. *Int J Oral Maxillofac Implants* 1996; **11**: 760–6.
26. Misch CM. Comparison of intraoral donor sites for onlay grafting prior to implant placement. *Int J Oral Maxillofac Implants* 1997; **12**: 767–76.
27. Khoury F. Augmentation of the sinus floor with mandibular bone block and simultaneous implantation: a 6-year clinical investigation. *Int J Oral Maxillofac Implants* 1999; **14**: 557–601.
28. Misch CM. Maxillofacial donor sites for sinus floor and alveolar reconstruction. In: Jensen OT, ed. *The sinus bone graft*. Chicago, IL: Quintessence, 2006: 130.
29. Buhr W, Coulon JP. Limits of the mandibular symphysis as a donor site for bone grafts in early secondary cleft palate osteoplasty. *Int J Oral Maxillofac Surg* 1996; **25**: 389–93.
30. Borstlap WA, Heidbuchel KLWM, Freihofer HPM, Kuijpers-Jagman AM. Early secondary bone grafting of alveolar cleft defects: a comparison between chin and rib grafts. *J Craniomaxillofac Surg* 1990; **18**: 201–5.
31. Hoppenreijs TJM, Nijdam ES, Freihofer HPM. The chin as a donor site in early secondary osteoplasty: a retrospective clinical and radiographic evaluation. *J Cranio Maxillofac Surg* 1992; **20**: 199–224.
32. Hunt DR, Jovanovic SA. Autogenous bone harvesting: a chin graft technique for particulate and monocortical bone blocks. *Int J Periodontics Restorative Dent* 1999; **19**: 165–73.

33. Zide MF. Autogenous bone harvest and bone compacting for dental implants. *Compend Contin Educ Dent* 2000; **21**: 585–90.
34. Peleg M, Garg AK, Misch CM, Mazor Z. Maxillary sinus and ridge augmentations using a surface-derived autogenous bone graft. *J Oral Maxillofac Surg* 2004; **62**: 1535–44.
35. Raghoebar GM, Louwerse C, Kalk WWI. Morbidity of chin bone harvesting. *Clin Oral Implant Res* 2001; **12**: 503–7.
36. Nkenke E, Schulze-Mosgau S, Radespiel M. Morbidity of harvesting of chin grafts: a prospective study. *Clin Oral Implant Res* 2001; **12**: 495–502.
37. Hallman M, Hedin M, Sennerby L. A prospective 1 year clinical and radiographic study of implants placed after maxillary sinus floor augmentation with bovine hydroxylapatite and autogenous bone. *J Oral Maxillofac Surg* 2002; **60**: 277–84.
38. Jensen J, Sindet-Pedersen S. Autogenous mandibular bone grafts and osseointegrated implants for reconstruction of severely atrophied maxilla: a preliminary report. *J Oral Maxillofac Surg* 1991; **49**: 1277–87.
39. Rubens BC, West RA. Ptosis of the chin and lip incompetence: consequences of lost mentalis support. *J Oral Maxillofac Surg* 1989; **4**: 359–66.
40. Cordaro L, Rossini C, Mijiritsky E. Fracture and displacement of lingual cortical plate of mandibular symphysis following bone harvesting: case report. *Implant Dent* 2004; **13**: 202–6.
41. Wood RM, Moore DL. Grafting of the maxillary sinus with intraorally harvested autogenous bone prior to implant placement. *Int J Oral Maxillofac Implants* 1988; **3**: 209–14.
42. Misch CM. Ridge augmentation using mandibular ramus bone grafts for the placement of dental implants: presentation of a technique. *Pract Periodontics Aesthet Dent* 1996; **8**: 127–35.
43. Misch CM. Use of the mandibular ramus as a donor site for onlay bone grafting. *J Oral Implantol* 2000; **26**: 42–9.
44. Smith BR, Rajchel JL, Waite DE, Read L. Mandibular anatomy as it relates to rigid fixation of the sagittal ramus split osteotomy. *J Oral Maxillofac Surg* 1991; **49**: 222–6.
45. Rajchel J, Ellis E, Fonseca RJ. The anatomic location of the mandibular canal; its relationship to the sagittal ramus osteotomy. *Int J Adult Orthod Orthognathic Surg* 1986; **1**: 37–42.
46. Miller CS, Nummikoski PV, Barnett DA, Langlais RP. Cross-sectional tomography. A diagnostic technique for determining the buccolingual relationship of impacted mandibular third molars and the inferior alveolar neurovascular bundle. *Oral Surg Oral Med Oral Pathol* 1990; **70**: 791–7.
47. Misch CM. The harvest of ramus bone in conjunction with third molar removal for onlay grafting prior to placement of dental implants. *J Oral Maxillofac Surg* 1999; **57**: 1376–9.
48. Hendy CW, Smith KG, Robinson PP. Surgical anatomy of the buccal nerve. *Br J Oral Maxillofac Surg* 1996; **34**: 457–60.
49. Ten Bruggenkate CM, Kraaijenhagen HA, van der Kwast WAM. Autogenous maxillary bone grafts in conjunction with placement of ITI endosseous implants: a preliminary report. *Int J Oral Maxillofac Surg* 1992; **21**: 81–4.
50. Misch CE. Maxillary sinus augmentation for endosteal implants: organized alternative treatment plans. *Int J Oral Implantol* 1987; **4**: 49–58.
51. Silva FM, Cortez AL, Moreira RW, Mazzonetto R. Complications of intraoral donor site for bone grafting prior to implant placement. *Implant Dent* 2006; **15**: 420–6.
52. Steiner M, Ramp WK. Short-term storage of freshly harvested bone. *J Oral Maxillofac Surg* 1988; **46**: 868–71.
53. Field EA. The use of powdered gloves in dental practice: a cause for concern? *J Dent* 1997; **25**: 209–14.
54. Hooe W, Steinberg B. Management of contaminated bone grafts. *Oral Surg Oral Med Oral Pathol* 1996; **82**: 34–7.
55. Misch CM. Implant therapy. In: Laskin DM, Abubacker AO, eds. *Decision making in oral and maxillofacial surgery*. Chicago: Quintessence, 2007: 18–24.
56. Whetzel TP, Sanders CJ. Arterial anatomy of the oral cavity: an analysis of vascular territories. *Plast Reconstr Surg* 1997; **100**: 582–7.
57. Misch CE. Bone augmentation for implant placement: keys to bone grafting. In: Misch CE, ed. *Contemporary implant dentistry*. St Louis, MO: Mosby, 1999: 457.
58. Misch CE, Moore PA. Steroids and the reduction of pain, edema and dysfunction in implant dentistry. *J Oral Implantol* 1989; **6**: 27–31.
59. Marx RE, Carlson ER, Eichstaedt RM. Platelet-rich plasma: growth factor enhancement for bone grafts. *Oral Surg Oral Med Oral Pathol* 1998; **85**: 638–46.
60. Monteleone K, Marx, RE, Ghurani R. Healing enhancement of skin graft donor sites with platelet rich plasma. Presented at the *82nd American Association of Oral and Maxilliofacial Surgeons Meeting*, San Francisco, CA, 22 September 2000.
61. Cromack DT, Porras-Reyes B, Mustoe TA. Current concepts in wound healing: growth factor and macrophage interaction. *J Trauma* 1990; 30; 129–33.
62. Carlson ER, Monteleone K. An analysis of inadvertent perforations of mucosa and skin concurrent with mandibular reconstruction. *J Oral Maxillofac Surg* 2004; **62**: 1103–7.
63. Lindeboom JA, van den Akker HP. A prospective placebo-controlled double-blind trial of antibiotic prophylaxis in intraoral bone grafting procedures: a pilot study. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2003; **96**: 669–72.
64. Lindeboom JA, Frenken JW, Tuk JG, Kroon FH. A randomized prospective controlled trial of antibiotic prophylaxis in intraoral bone-grafting procedures: preoperative single-dose penicillin versus preoperative single-dose clindamycin. *Int J Oral Maxillofac Surg* 2006; **35**: 433–6.
65. Scharf DR, Tarnow DP. Success rates of osseointegration for implants placed under sterile versus clean conditions. *J Periodontol* 1993; **64**: 954–6.
66. Young MP, Korachi M, Carter DH, Worthington HV, McCord JF, Drucker DB. The effects of an immediately pre-surgical chlorhexidine oral rinse on the bacterial contaminants of bone debris collected during dental implant surgery. *Clin Oral Implants Res* 2002; **13**: 20–9.
67. Brånemark PI, Grondahl K, Worthington P. *Osseointegration and autogenous onlay bone grafts: reconstruction of the edentulous atrophic maxilla*. Chicago, IL: Quintessence, 2001: 112–34.

68. Wang JH, Waite DE, Steinhauser E. Ridge augmentation: an evaluation and follow-up report. *J Oral Surg* 1976; **34**: 600–2.
69. Manson PN. Facial bone healing and bone grafts. A review of clinical physiology. *Clin Plast Surg* 1994; **21**: 331–48.
70. Burchardt H. The biology of bone graft repair. *Clin Orthop Relat Res* 1983; **174**: 28–42.
71. Smith JD, Abramson M. Membranous vs. endochondral autografts. *Arch Otolaryngol* 1974: **99**; 203–9.
72. Zins JE, Whitaker LA. Membranous vs endochondral autografts: implications for craniofacial reconstruction. *Plast Reconstruct Surg* 1983; **72**: 778–85.
73. Dado DV, Izquiedo R. Absorption of onlay bone grafts in immature rabbits: membranous versus endochondral bone and bone struts versus paste. *Ann Plast Surg* 1989; **23**: 39–48.
74. Lin KY, Barlett SP, Yaremchuk MJ. The effect of rigid fixation on the survival of onlay bone grafts: an experimental study. *Plast Reconstruct Surg* 1990; **86**: 449–56.
75. Hardesty RA, Marsh JL. Craniofacial onlay bone grafting: a prospective evaluation of graft morphology, orientation and embryonic origin. *Plast Reconstruct Surg* 1990; **85**: 5–14.
76. Ozaki W, Buchman SR. Volume maintenance of onlay bone grafts in the craniofacial skeleton: micro-architecture versus embryologic origin. *Plast Reconstr Surg* 1998; **102**: 291–9.
77. Proussaefs P, Lozada J, Kleinman A. The use of ramus autogenous block grafts for vertical alveolar ridge augmentation and implant placement: a pilot study. *Int J Oral Maxillofac Implants* 2002; **17**: 238–48.
78. Nystrom E, Ahlqvist J, Kahnberg KE, Rosenquist JB. Autogenous onlay bone grafts fixed with screw implants for the treatment of severely resorbed maxillae. Radiographic evaluation of preoperative bone dimensions, postoperative bone loss, and changes in soft-tissue profile. *Int J Oral Maxillofac Surg* 1996; **25**: 351–9.
79. Carvalho P, Vasconcellos L, Pi J. Influence of bed preparation on the incorporation of autogenous bone grafts: a study in dogs. *Int J Oral Maxillofac Implants* 2000; **15**: 565–70.
80. Gielkens PF, Bos RR, Raghoebar GM, Stegenga B. Is there evidence that barrier membranes prevent bone resorption in autologous bone grafts during the healing period? A systematic review. *Int J Oral Maxillofac Implants* 2007; **22**: 390–8.
81. Rasmusson L, Meredith N, Kahnberg KE, Sennerby L. Effects of barrier membranes on bone resorption and implant stability in onlay bone grafts. An experimental study. *Clin Oral Implants Res* 1999; **10**: 267–77.
82. Dongieux JW, Block MS, Morris G, Gardiner D. The effect of different membranes on onlay bone graft success in the dog mandible. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1998; **86**: 145–51.
83. Buser D, Dula K, Hirt HP, Schenk RK. Lateral ridge augmentation using autografts and barrier membranes: a clinical study with 40 partially edentulous patients. *J Oral Maxillofac Surg* 1996; **54**: 420–32.
84. Von Arx T, Buser D. Horizontal ridge augmentation using autogenous block grafts and the guided bone regeneration technique with collagen membranes: a clinical study with 42 patients. *Clin Oral Implants Res* 2006; **17**: 359–66.
85. Boyne P, Peetz M. *Osseous reconstruction of the maxilla and mandible: surgical techniques using titanium mesh and bone mineral*. Carol Stream, IL: Quintessence, 1997: 1–100.
86. Von Arx T, Wallkamm B, Hardt N. Localized ridge augmentation using a micro titanium mesh: a report on 27 implants followed 1 to 3 years after functional loading. *Clin Oral Implant Res* 1998; **9**: 123–30.
87. Krennmair G, Krainhofner M, Weinlander M, Piehslinger E. Provisional implants for immediate restoration of partially edentulous jaws: a clinical study *J Oral Maxillofac Implants* 2008; **23**: 717–25.
88. Becktor JP, Eckert SE, Isaksson S, Keller EE. The influence of mandibular dentition on implant failures in bone grafted edentulous maxillae. *Int J Oral Maxillofac Implants* 2002; **17**: 69–77.
89. Jones JK, Triplett RG. The relationship of cigarette smoking to impaired intraoral wound healing: a review of evidence and implications for patient care. *J Oral Maxillofac Surg* 1992; **50**: 237–9.
90. Levin L, Schwartz-Arad D. The effect of cigarette smoking on dental implants and related surgery. *Implant Dent* 2005; **14**: 357–61.
91. Jorenby DE, Leischow SJ, Nides MA. A controlled trial of sustained-release bupropion, a nicotine patch, or both for smoking cessation. *N Engl J Med* 1999; **340**: 685–9.
92. Weyant RJ. Characteristics associated with the loss and peri-implant tissue health of endosseous implants. *Int J Oral Maxillofac Implants* 1994; **9**: 95–102.
93. Bain CA, Moy PK. The association between the failure of dental implants and cigarette smoking. *Int J Oral Maxillofac Implants* 1993; **8**: 609–15.
94. American Dental Association Council on Scientific Affairs. Dental management of patients receiving oral bisphosphonate therapy: expert panel recommendations. *J Am Dent Assoc* 2006; **137**: 1144–50.
95. Jeffcoat MK. Safety of oral bisphosphonates: controlled studies on alveolar bone. *Int J Oral Maxillofac Implants* 2006; **21**: 349–53.
96. Fugazzotto PA, Lightfoot WS, Jaffin R, Kumar A. Implant placement with or without simultaneous tooth extraction in patients taking oral bisphosphonates: postoperative healing, early follow-up, and the incidence of complications in two private practices. *J Periodontol* 2007; **78**: 1664–9.
97. Grant BT, Amenedo C, Freeman K, Kraut RA. Outcomes of placing dental implants in patients taking oral bisphosphonates: a review of 115 cases. *J Oral Maxillofac Surg* 2008; **66**: 223–30.
98. Bell BM, Bell RE. Oral bisphosphonates and dental implants: a retrospective study. *J Oral Maxillofac Surg* 2008; **66**: 1022–4.
99. Qingyun, X, Haisheng, L, Xuenong, Z, Mathias, B. The influence of alendronate treatment and bone graft volume on posterior lateral spine fusion in a porcine model. *Spine* 2005; **30**: 1116–21.
100. Astrand J, Harding AK, Aspenberg P, Tägil M. Systemic zoledronate treatment both prevents resorption of allograft bone and increases the retention of new formed bone dur-

ing revascularization and remodelling. A bone chamber study in rats. *BMC Musculoskelet Disord* 2006; **4**; 63.
101. Altundal H, Sayrak H, Yurtsever E, Göker K. Inhibitory effect of alendronate on bone resorption of autogenous free bone grafts in rats. *J Oral Maxillofac Surg* 2007; **65**: 508–16.
102. American Association of Oral and Maxillofacial Surgeons. *Position Paper on bisphosphonate-related osteonecrosis of the jaws*. Rosemont, IL: AAOMS, 2006.
103. Adell R, Lekholm U, Grondahl K, Brånemark PI, Lindstrom J, Jacobsson M. Reconstruction of severely resorbed edentulous maxillae using osseointegrated fixtures in immediate autogenous bone grafts. *Int J Oral Maxillofac Implants* 1990; **5**: 233–46.
104. Friberg B. Bone augmentation at single-tooth implants using mandibular grafts: a one-stage surgical procedure. *Int J Periodontics Restorative Dent* 1995; **15**: 436–45.
105. Matsumoto MA, Filho HN, Francishone CE. Microscopic analysis of reconstructed maxillary alveolar ridges using autogenous bone grafts from the chin and iliac crest. *Int J Oral Maxillofac Implants* 2002; **17**: 507–16.
106. Buser D, Ingimarsson S, Dula K. Long-term stability of osseointegrated implants in augmented bone: a 5-year prospective study in partially edentulous patients. *Int J Periodontics Restorative Dent* 2002; **22**: 108–17.
107. Attard NJ, Zarb GA. Immediate and early implant loading protocols: a literature review of clinical studies. *J Prosthet Dent* 2005; **94**: 242–58.
108. Misch CE, Dietsh F. Endosteal implants and iliac crest grafts to restore severely resorbed totally edentulous maxillae – a retrospective study. *J Oral Implantol* 1994; **20**: 100–10.
109. Raghoebar GM, Batenburg RH, Vissink A, Reintsema H. Augmentation of localized defects of the anterior maxillary ridge with autogenous bone before insertion of implants. *J Oral Maxillofac Surg* 1996; **54**: 1180–15.
110. Reinert S, König S, Bremerich A, Eufinger H, Krimmel M. Stability of bone grafting and placement of implants in the severely atrophic maxilla. *Br J Oral Maxillofac Surg* 2003; **41**: 249–55.
111. Donos N, Mardas N, Chadha V. Clinical outcomes of implants following lateral bone augmentation: systematic assessment of available options (barrier membranes, bone grafts, split osteotomy). *J Clin Periodontol* 2008; **35** (8 Suppl): 173–202.
112. Becktor JP, Isaksson S, Sennerby L. Survival analysis of endosseous implants in grafted and nongrafted edentulous maxillae. *Int J Oral Maxillofac Implants* 2004; **19**: 107–15.
113. Tonetti MS, Hämmerle CH. European Workshop on Periodontology Group C. Advances in bone augmentation to enable dental implant placement: Consensus Report of the Sixth European Workshop on Periodontology. *J Clin Periodontol* 2008; **35** (8 Suppl): 168–72.

Chapter 14

Complications in guided bone regeneration

Filippo Fontana DDS, MS, *Isabella Rocchietta* DDS, *and Massimo Simion* MD, DDS

Introduction

Guided bone regeneration (GBR) is one of several surgical techniques that have been developed in the past two decades to regenerate bone and thus to allow implant placement in compromised sites. It is a surgical procedure that consists of the placement of a cell-occlusive physical barrier between the connective tissue and the alveolar bone defect (1, 2). This barrier prevents the migration of the soft tissue into the defect and creates a protected space in which the blood clot and the graft are stabilized. Epithelial and connective tissue cell migration is avoided and the slow migrating osteogenic cells can proliferate, with subsequent formation of new bone (3, 4). The principles of GBR have been developed on the basis of guided tissue regeneration introduced by the Scandinavian research team under Nyman, Gottlow, and Karring, who conducted several animal experiments (5–7) and human clinical studies on periodontal regeneration (8, 9). These concepts were first applied to bone regeneration by Dahlin *et al.* (4) in an experimental study.

There is scientific evidence demonstrating that GBR is a successful and predictable technique to regenerate bone in both the horizontal and the vertical dimension (10, 11). However, the use of a barrier membrane has several potential drawbacks. It is generally agreed that bone regeneration using GBR is a technically sensitive procedure, in which the skill and experience of the surgeon play a central role in both the success of the treatment outcome and the incidence of complications. The most common complication is the premature exposure of the membrane to the oral environment and its sequelae. However, other complications have been reported.

A classification of the complications related to GBR procedures has never been proposed. Verardi (12), discussing the treatment options for expanded polytetrafluoroethylene (e-PTFE) membranes that become exposed, suggested a division of the exposures into class I and class II categories. Class I was defined as a small soft-tissue fenestration (≤3 mm) and class II as a wider opening (>3 mm).

On the basis of the evidence emerging from clinical practice, a possible classification of complications in GBR with non-absorbable membranes can be suggested:

- Exposure and infection of the membrane:
  - class I: small membrane exposure (≤3 mm) without purulent exudation
  - class II: large membrane exposure (>3 mm) without purulent exudation
  - class III: membrane exposure with purulent exudation
  - class IV: abscess formation without membrane exposure
- Lesions associated with periosteal releasing incision.

Literature review

The incidence of membrane exposure varies depending on the study and on the clinical use of the barrier technique. When e-PTFE membranes were introduced in the early 1990s to augment the alveolar ridge laterally, a 41% incidence of exposure was reported (13). This number has since been drastically reduced as a result of improvements in the surgical technique. Today, in large part owing to these improvements, GBR is considered to be a highly predictable technique to regenerate bone.

In 1996 Buser *et al.* (14) evaluated the treatment outcome of the combined application of an autograft and e-PTFE membrane to achieve horizontal ridge augmentation. They reported a 2.5% incidence of soft-tissue dehiscence in 40 treated sites. Tinti (15) experienced one exposure with six e-PTFE membranes positioned to augment the bone vertically. Simion *et al.* (16) recorded an 18% rate of healing complications when using a membrane technique and autogenous bone or allografts to augment vertically the ridge around dental implants in humans. When vertical ridge augmentation was performed in conjunction with sinus elevation Simion *et al.* (17) reported a 12.5% membrane exposure. More recently, the same authors (18) combined an e-PTFE membrane and auto/xenograft in a 1:1 ratio, resulting in an incidence

of complications of 18%, while Merli *et al.* (19), in a clinical trial to compare two different techniques for vertical ridge augmentation, reported one major complication with 11 non-absorbable membranes.

Fontana *et al.* (20), in a prospective study to compare allogenous bone matrix to the autograft to augment alveolar ridges vertically, reported one membrane exposure in ten surgically treated sites.

Recently, in a systematic review on the use of non-absorbable membranes for vertical ridge augmentation, a range of complications varying from 0% to 45.5% was reported (10).

Once exposed to the oral environment, microorganisms can invade the surface and pass through the membrane (21). In this study the authors concluded that bone regeneration under an e-PTFE membrane stops 2–3 mm from the contaminated surface of the membrane. Further experimental and clinical results (22) noted that bacterial penetration is delayed by the low porosity of the e-PTFE membrane texture. According to this study, the colonization of the regenerating tissue starts 3–4 weeks after exposure. This period can be assumed as the critical time for membrane removal to avoid infection to the deeper tissues.

Chlorhexidine has been proposed to reduce bacterial contamination of exposed membranes. In an *in vitro* study (23) topical application twice a day of a 0.2% chlorhexidine gel proved to be effective in reducing the amount of bacteria and inflammation to the surrounding soft tissues. Nevertheless, the use of chlorhexidine in this study did not influence the rapidity of bacterial penetration through the thickness of the membrane.

Prevention of complications: surgical technique

Vertical and horizontal ridge augmentation by means of GBR with e-PTFE membranes is believed to be the most technically sensitive among all GBR procedures. Therefore, proper surgical techniques combined with the technical skill of the surgeon are essential for a successful and predictable outcome. See Figs 14.1–14.27.

Preoperative and postoperative care

The surgical procedure is performed in a surgical operation in a private office with strict hygienic conditions. Presurgical preparation of the patient consists of use of a chlorhexidine digluconate 0.2% mouthrinse (Corsodyl; GlaxoSmithKline) for 2 minutes and an extraoral scrub with a povidone–iodine solution (Betadine; Viatris). A sedative premedication with diazepam (20–30 gtt, Valium-2; Roche) is administered before the surgery. Local anesthesia consists of the administration of articaine 4% with epinephrine 1:100 000 (Citocartin 100; Molteni Dental). The patient is prescribed antibiotics (amoxicillin 875 mg and clavulanic acid 125 mg; Augmentin; GlaxoSmithKline) starting 1 day before surgery and then twice a day for 1 week. The patient also receives a non-steroidal anti-inflammatory agent starting 1 hour before the surgery and twice a day for 1 week. Local plaque control is essential and chlorhexidine 0.12% mouthrinses are prescribed for use twice a day, to reduce bacterial contamination of the wound. The patient is recalled once a month. Radiographic examination is done at the end of the surgery and at the time of membrane removal.

Flap design and recipient site preparation

The meticulous preparation of the recipient site is one of the key points for a successful outcome of the surgical procedure (Figs 14.1–14.6). The surgery starts with a crestal incision down to bone within the keratinized mucosa of the edentulous ridge. The incision extends intrasulcularly to include one or two distally and mesially adjacent teeth. Two vertical releasing incisions are made buccally at the distal and mesial termination of the crestal incision. Buccal and palatal full-thickness flaps are elevated to obtain a wide access for membrane and eventual implant placement. A continuous releasing periosteal incision is made at the base of the buccal flap, connecting the mesial and distal vertical incisions to help obtain a completely tension-free closure (Fig. 14.5). In the lower jaw particular care must be taken to avoid any damage to the mental nerve and to avoid damaging the vascular plexuses of the floor of the mouth. Moreover, the lingual flap must be reflected beyond the mylohyoid insertion of the omohyoid muscle, to allow coronal advancement of the flap (Fig. 14.6). No periosteal incision is performed with the palatal flap in the upper jaw. The flaps must be carefully managed to avoid any soft-tissue trauma or perforation that could lead to membrane exposure during the healing period. After the flaps have been released, curettage of the bone surface is essential to remove all remaining connective tissue and periostium that could interfere with the regenerative procedure.

Membrane positioning

When a large volume of bone must be regenerated with the GBR technique, a titanium reinforced e-PTFE membrane (Gore-Tex; WL Gore, Flagstaff, AZ) is recommended (Figs 14.7–14.9). Better results with non-absorbable membranes than with absorbable ones are due to better space-maintaining abilities, controlled time of barrier function and lack of a resorption process. The membrane is contoured and trimmed to adapt to the ridge and to a predetermined width and height of the area to be aug-

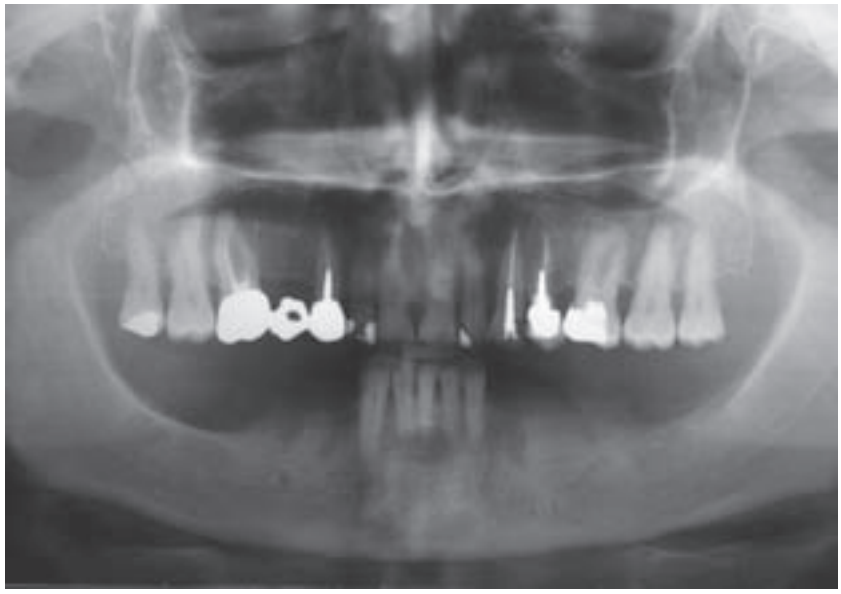


Fig. 14.1 Orthopantomogram of the bilateral partial edentulism in the mandible showing advanced atrophies.

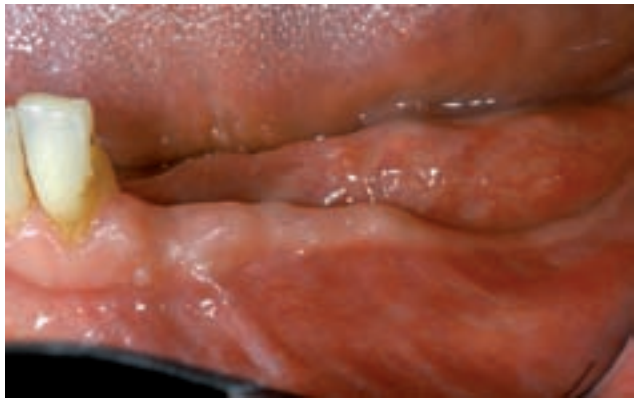


Fig. 14.2 Lateral view of the defect in the posterior left mandible that requires a horizontal ridge augmentation to allow implant placement.

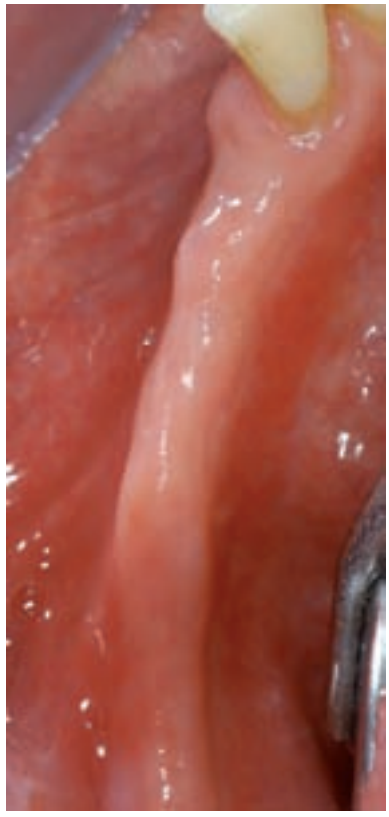


Fig. 14.3 Occlusal view of the same defect.

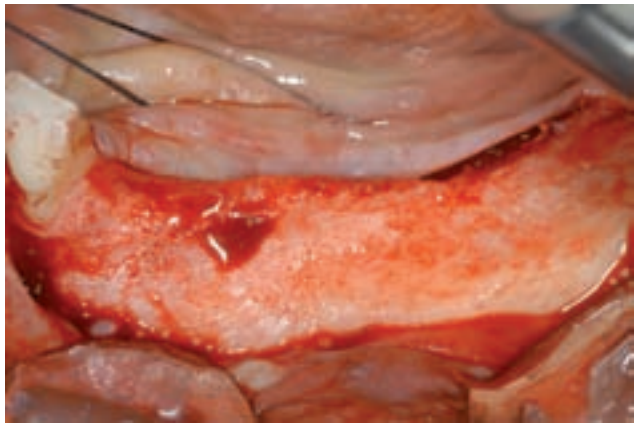


Fig. 14.4 After buccal and lingual flaps are gently elevated, the bone defect is curetted and prepared for the regenerating procedure.

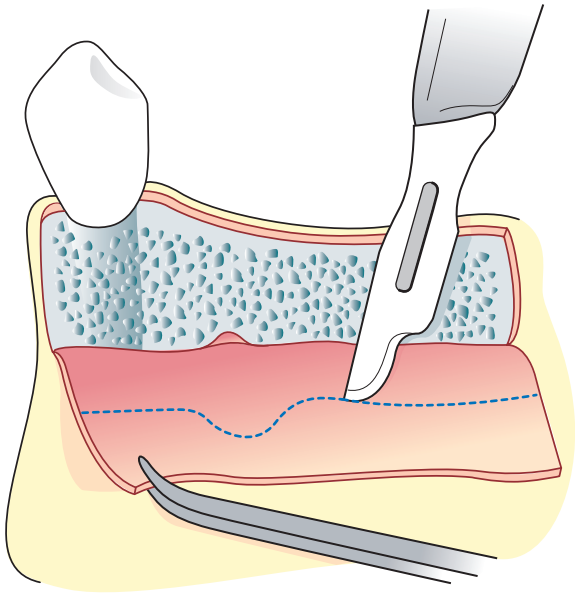


Fig. 14.5 Illustration showing the releasing periosteal incision of the buccal flap.

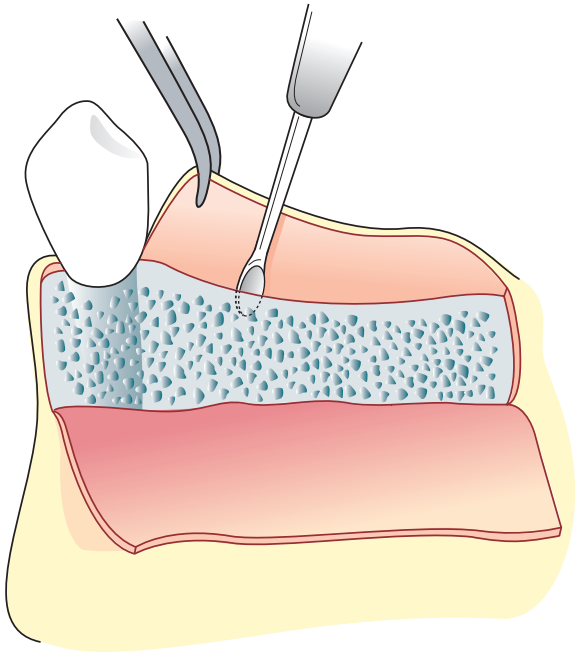


Fig. 14.6 Illustration showing the releasing of the lingual flap.

mented. To avoid any interference during the healing process, the membrane should not touch the periodontal ligament of the adjacent teeth and should overlap the residual crestal bone by a minimum of 3–4 mm.

Stainless steel miniscrews (6–12 mm in length; Omnia) are used as "poles" to support the membrane. They are positioned in the residual bone and left to protrude for the required height and/or width. However, when the residual bone height is at least 6 mm and primary

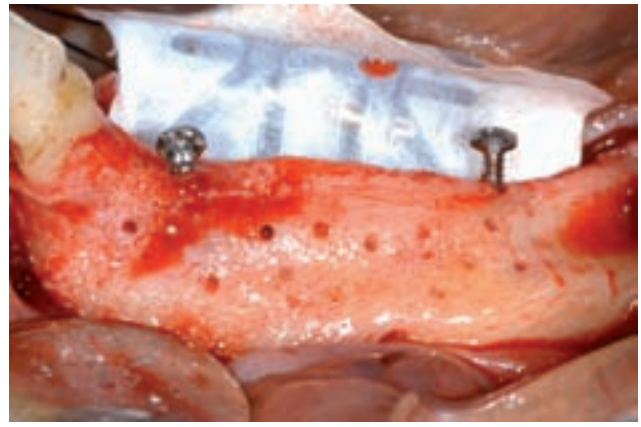


Fig. 14.7 A titanium-reinforced e-PTFE membrane is fixed lingually with miniscrews and several bone perforations are performed to ensure bleeding necessary for bone formation.

Fig. 14.8 The 1:1 combination of autogenous bone graft collected with a bone scraper from the retromolar area and deproteinized bovine bone (Bio-Oss).

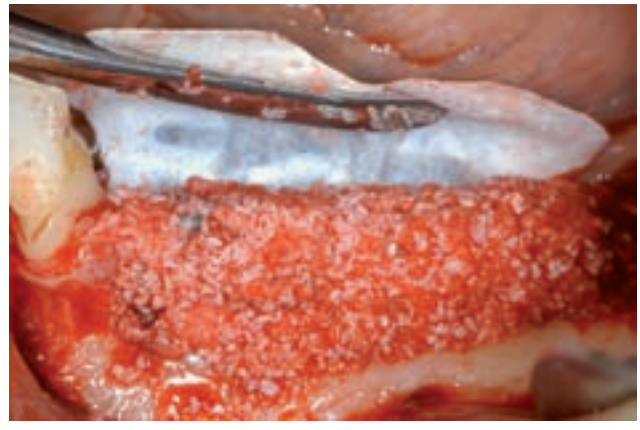


Fig. 14.9 The bone graft is packed into the defect.

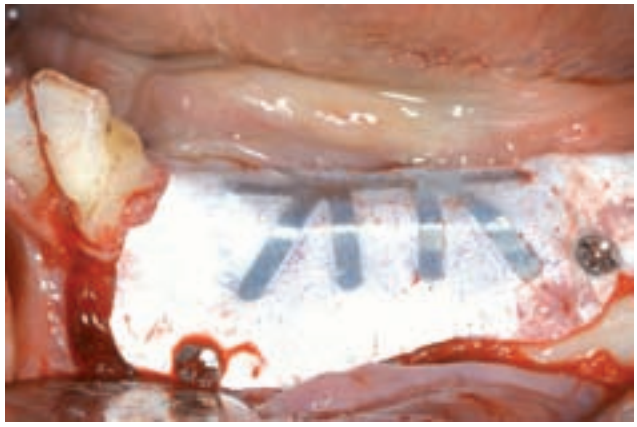


Fig. 14.10 The membrane is gently pulled and fixed buccally with two miniscrews.

implant stability can be achieved, the implants may be inserted simultaneously with membrane positioning. For vertical augmentation implants are left to protrude from the cortical bone and act as miniscrews. Several drill holes must be made on the cortical bone to ensure the bleeding necessary to promote the required blood clot formation (24). Once positioned in the recipient site, the membrane is lingually stabilized with fixation miniscrews (Omnia) in the mandible (Fig. 14.7) and with titanium tacks (Maxill) in the maxilla. A particulated bone graft is then placed on the bone crest under the partially fixated membrane (Figs 14.8, 14.9). The membrane is gently pulled buccally over the graft and fixated at the mesial and distal buccal borders to achieve optimal flap adaptation (Fig. 14.10).

Bone graft

There is scientific evidence (15, 16, 25, 26) demonstrating that the use of a bone graft to fill the space under the e-PTFE membrane increases the potential and the predictability of bone regeneration as well as bone-to-implant contact. The rationale for using a bone graft in association with GBR includes the fact that it provides membrane support and acts as a scaffold for bone formation. A wide variety of graft materials has been used in experimental studies and in clinical practice. However, many of these materials lack adequate scientific evidence to support their use in GBR. Autogenous bone grafts, collected from both intraoral and extraoral donor sites, are considered to be the gold standard in bone regeneration (14–16, 27); however, morbidity and patient discomfort associated with harvesting procedures must be taken in consideration. Autogenous bone grafts are usually harvested from the mandibular ramus and/or from the mental symphysis with a bone scraper or with trephine burs.

In order to avoid the disadvantages associated with autogenous bone harvesting, some authors have suggested the use of a bone substitute or of a combination graft (28–30).

Allogenous bone grafts have been proposed for use with GBR. Fontana *et al.* (20) provided histologic and clinical evidence for the use of an allogenous bone matrix to obtain vertical ridge augmentation. Similar results were reported by Simion *et al.* with the use of demineralized freeze-dried bone allograft (16, 31).

Deproteinized bovine bone has been also recommended (32–36) for use with GBR techniques with both absorbable and non-absorbable membranes.

Even though to date only a few reports have been published using autogenous bone grafts combined with a xenograft and a non-absorbable membrane (18), emerging clinical evidence suggests a 1:1 ratio of autograft and deproteinized bovine bone. This mixture combines the scaffold properties of a bone substitute with the osteogenic and osteoinductive properties of the autograft.

Suturing

A precise suturing technique is essential for successful healing (Figs 14.11–14.13). The sutures function to maintain the soft-tissue flaps in the advanced position made possible by the periosteal releasing incisions. Therefore, before suturing, the surgeon must clinically evaluate the coronal extension of both flaps. Ideally, they should overlap each other by at least 10 mm. Suturing consists of two lines of closure. Horizontal mattress sutures with U stitches should be used first to ensure proper flap apposition, with the connective tissue surfaces facing each other by at least 3 mm. Subsequently, interrupted sutures are placed between the horizontal mattress sutures and used to close the vertical incisions. Sutures are removed 12–15 days after surgery (Fig. 14.14). The use of an e-PTFE non-absorbable monofilament suture (Gore-Tex suture) is recommended.

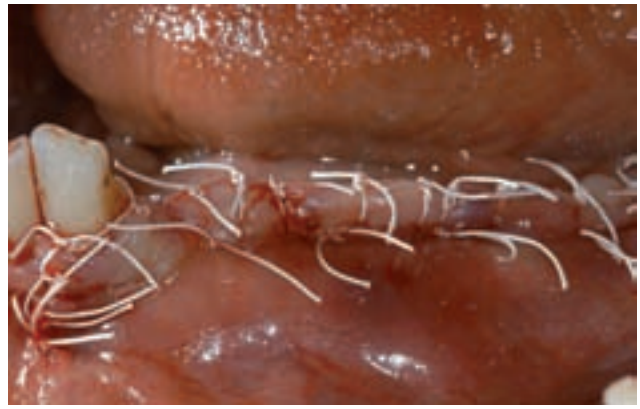


Fig. 14.11 Suturing technique with two lines of closure: first, horizontal mattress sutures to overlap the two flaps, and then single interrupted stitches.

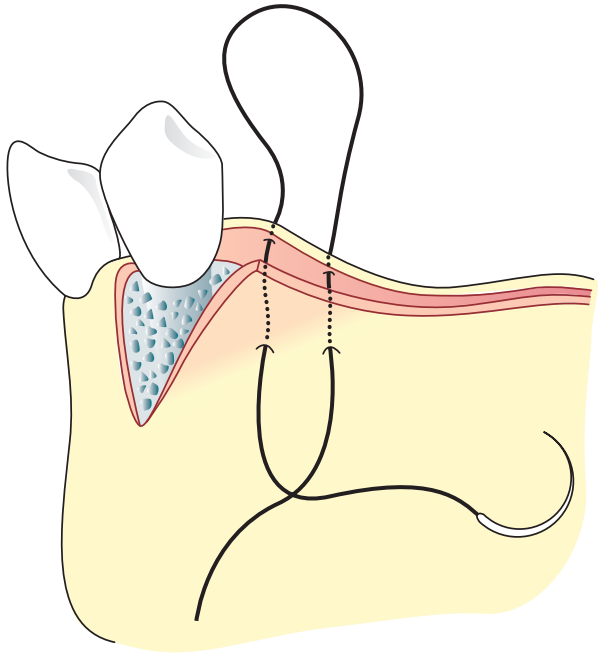


Fig. 14.12 Illustration showing the horizontal mattress suture.

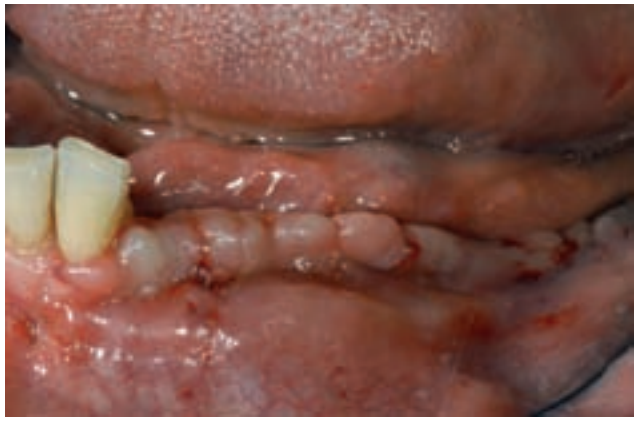


Fig. 14.14 Suture removal after 15 days.

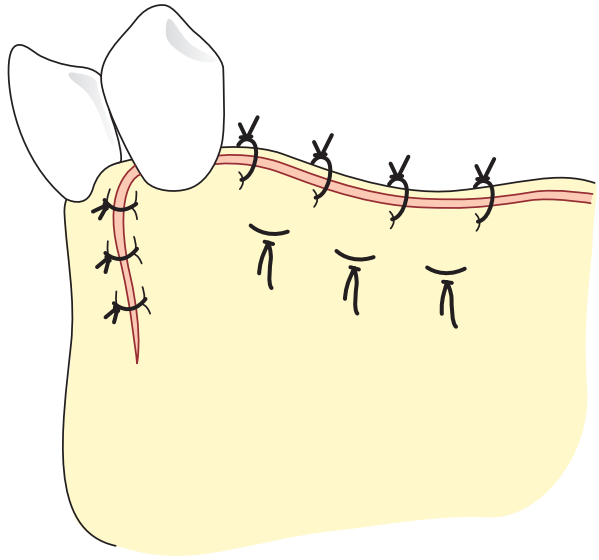


Fig. 14.13 Illustration showing the suturing technique.

Membrane removal

The e-PTFE membrane is a non-absorbable membrane; therefore, a second surgery is required to remove the e-PTFE membranes. These membranes should remain completely submerged and in place for 6–8 months (Figs 14.15, 14.16) depending on the volume of bone to be regenerated. This period is considered the optimal healing time to obtain sufficient regeneration and maturation of the new bone (13, 37). Membrane removal is performed with a crestal incision and with mesial and distal vertical releasing incisions. Two full-thickness flaps are then elevated buccally and lingually/palatally to localize and to remove the miniscrews (or the tacks in the upper jaw). The membrane is gently dissected from the bone (Figs 14.17–14 19). Usually a connective tissue-like

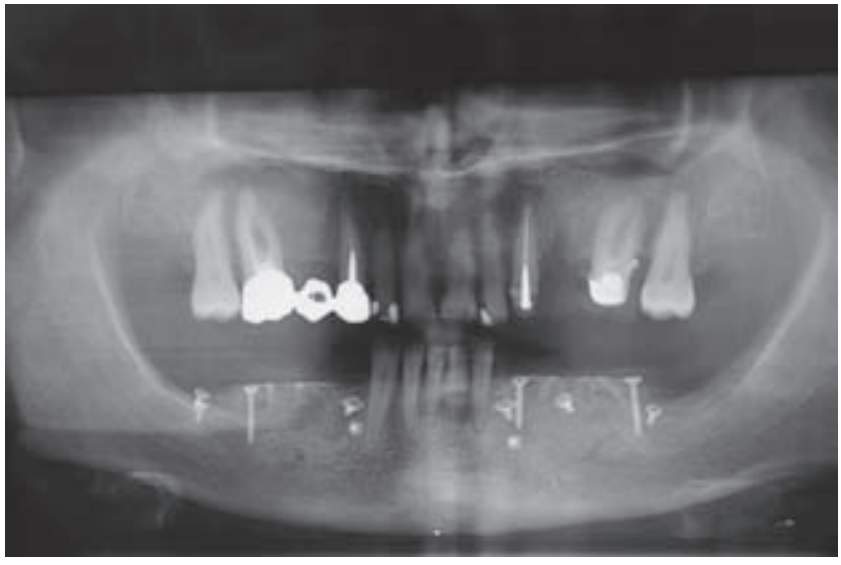


Fig. 14.15 Orthopantomogram after bilateral guided bone regeneration with e-PTFE membranes.

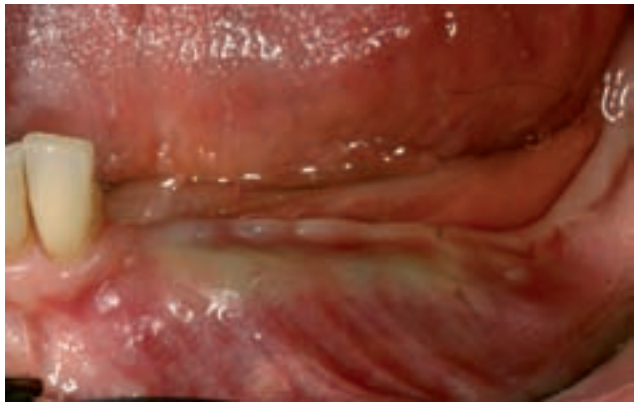


Fig. 14.16 Lateral view of the regenerated area after 8 months of submerged uneventful healing.

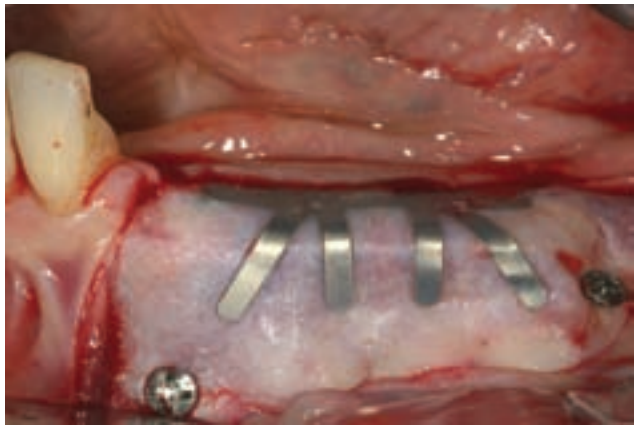


Fig. 14.17 Membrane removal. Two full-thickness flaps are elevated to localize and remove the miniscrews.

soft-tissue layer is present coronal to the vertically regenerated bone (38). It is about 1 mm thick and it can be used to suture the buccal flap in a more apical position to augment the keratinized mucosa where necessary.

Implant insertion

Implants can be placed with a simultaneous or with a staged approach. When there is sufficient residual bone to allow primary implant stability (≥ 6 mm), fixtures are inserted at the time of the vertical augmentation procedure. Therefore, placing the healing abutments coincides with membrane removal. In the staged approach, implants are placed at time of membrane removal after at least 6–8 months of submerged membrane healing (Figs 14.20–14.22). Occasionally, when there is observed to be an insufficient band of keratinized tissue (Figs 14.23, 14.24), a soft-tissue graft from the palate is necessary to augment this tissue. The graft may be performed at time of abutment insertion or before final restoration (Figs 14.24–14.27).

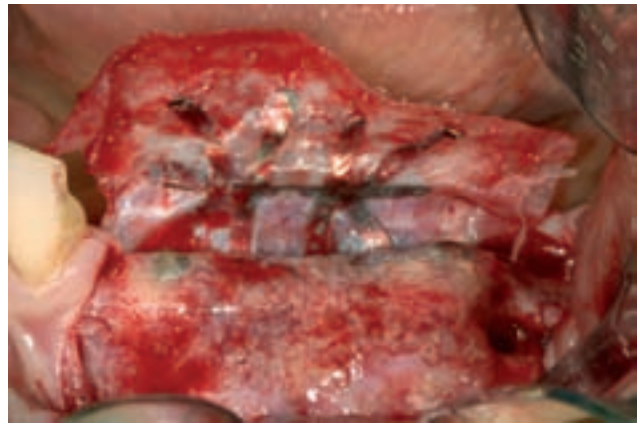


Fig. 14.18 The membrane is gently dissected from the regenerated area.

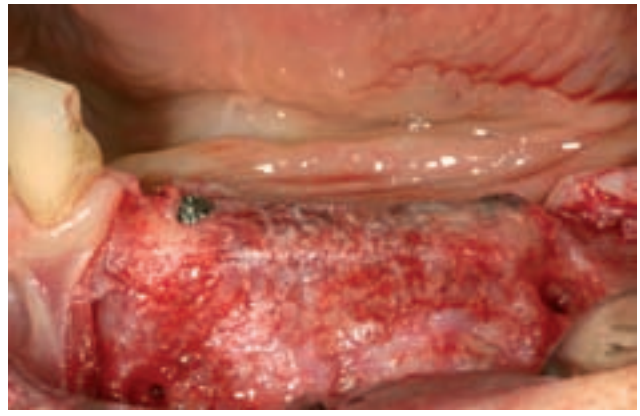


Fig. 14 19 The regenerated area has a clinical appearance of bone.

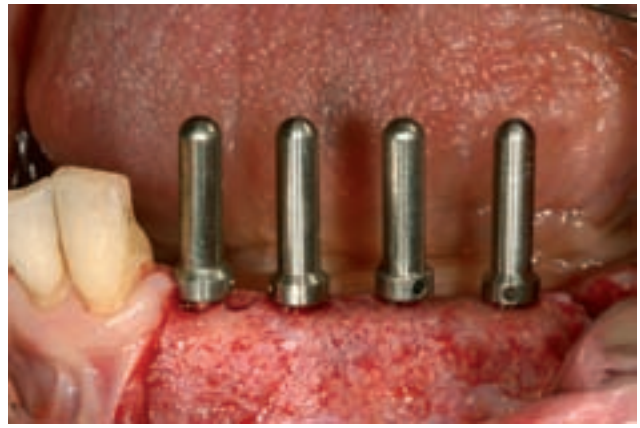


Fig. 14.20 Surgical direction indicators have been used to insert the implant in the proper way.

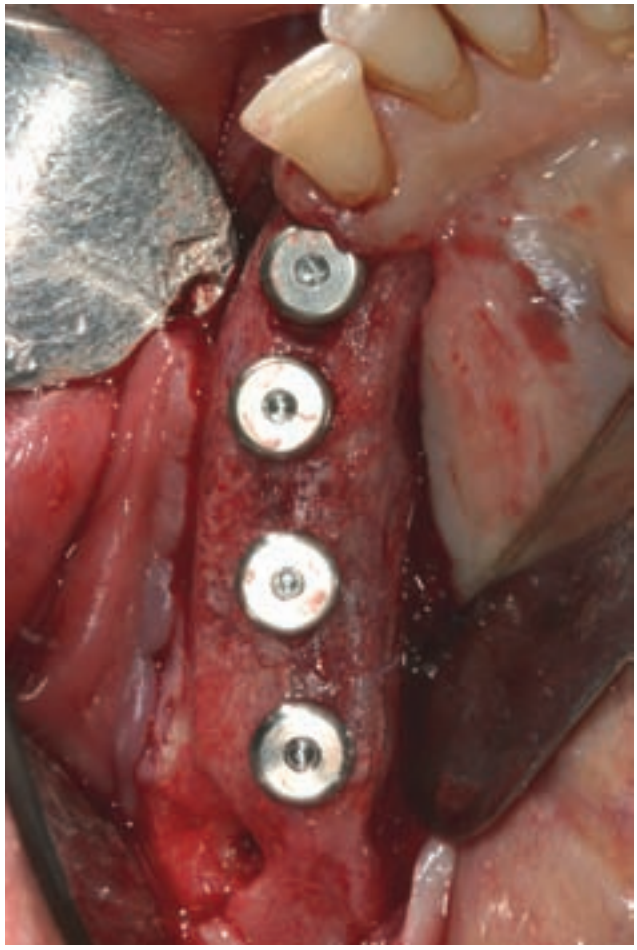


Fig. 14.21 Occlusal view of the implants positioned.

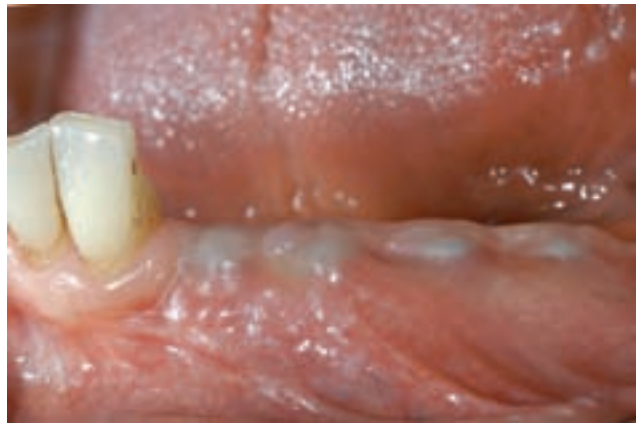


Fig. 14.23 At implant reopening, a mucogingival surgical procedure is necessary to create an adequate width of attached keratinized mucosa.

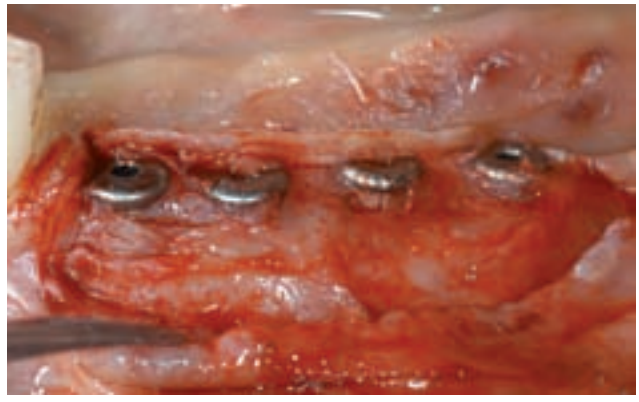


Fig. 14.24 A partial-thickness flap has been elevated at the recipient site.

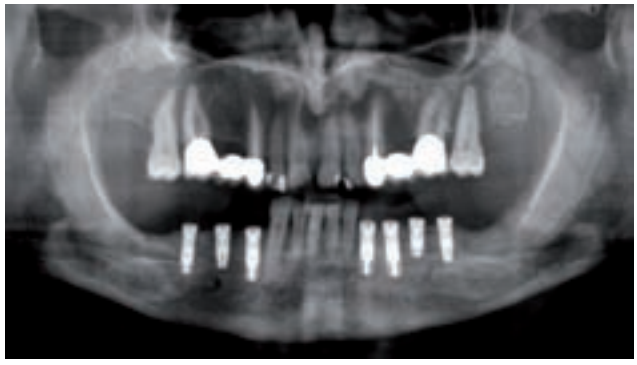


Fig. 14.22 Orthopantomogram showing implant placement in the regenerated areas.

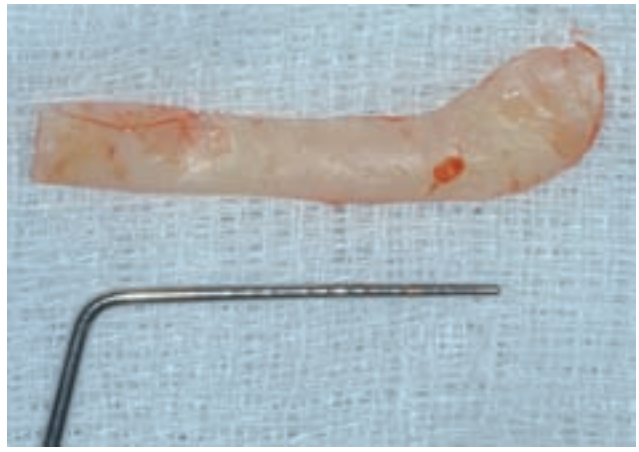


Fig. 14.25 A free gingival graft is collected from the palate.

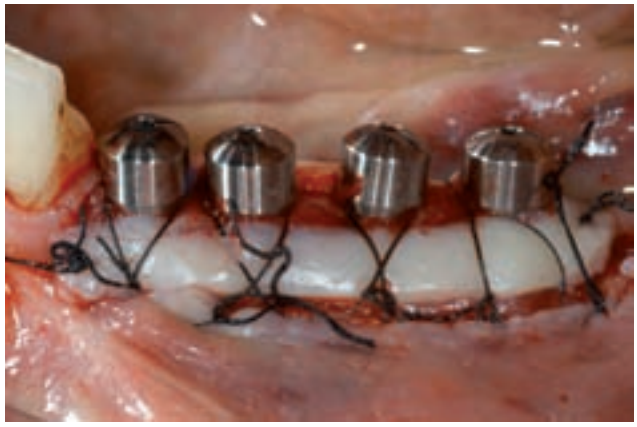


Fig. 14.26 The gingival graft is sutured in placed with suspended sutures.

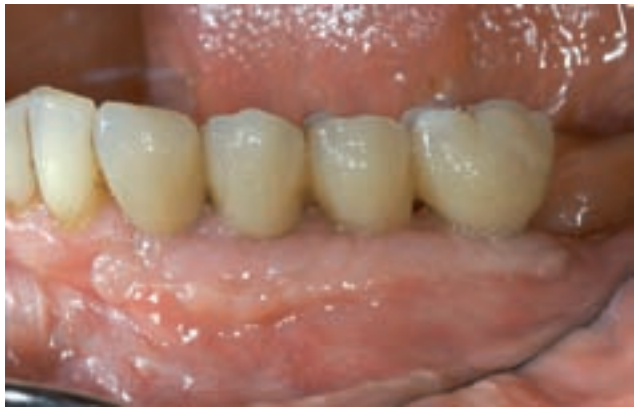


Fig. 14.27 Temporary crowns are positioned after 2 months of soft-tissue healing.

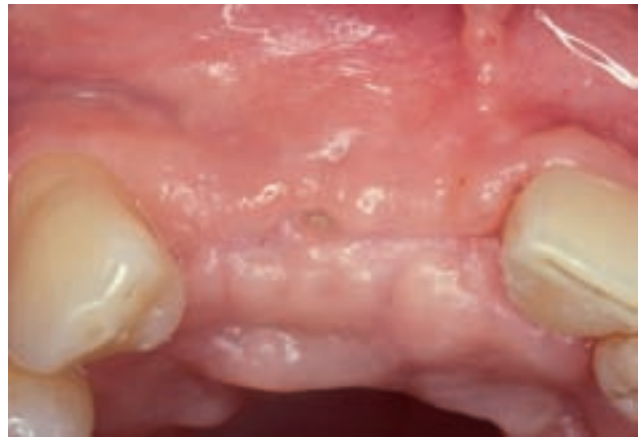


Fig. 14.28 A small exposure of the e-PTFE membrane is present 1 month after the regenerative procedure.

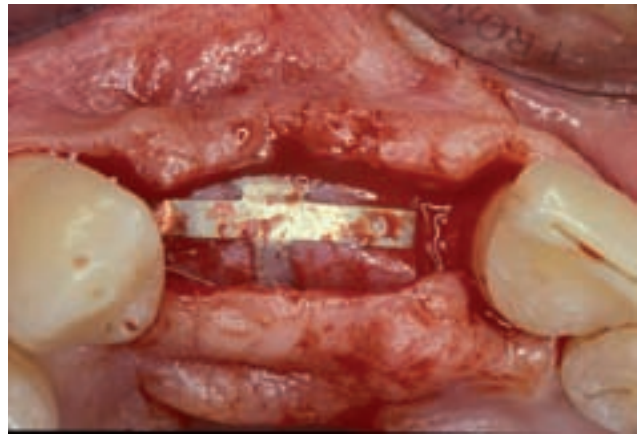


Fig. 14.29 A mucoperiosteal flap is elevated to isolate the e-PTFE membrane.

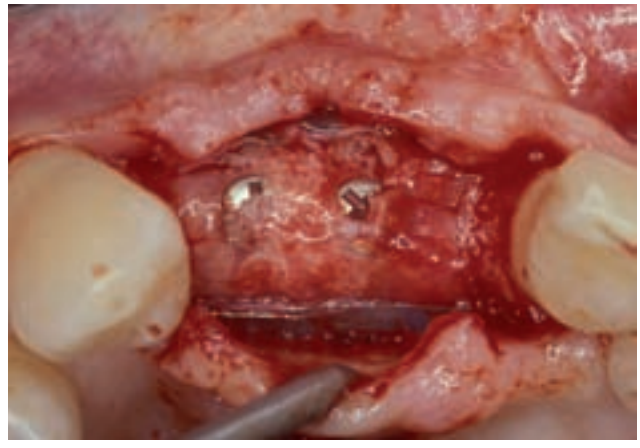


Fig. 14.30 The part of the membrane exposed to the oral environment is cut with scissors and removed, leaving the residual membrane in place. Note that regenerating tissue similar to bone is detectable.

Clinical management of guided bone regeneration complications

Exposure and infection of the membrane

Membrane exposure to the oral environment is considered to be the most common complication of GBR. When a membrane is exposed, the amount of the regenerating tissue under the barrier is negatively influenced, as reported in animal studies (39–41) and in clinical investigations (1, 2, 13, 42–44). The consequences of wound dehiscence and membrane exposure range from a minor problem necessitating membrane removal with a resultant incomplete bone growth to a major problem including treatment failure and implant loss with additional cost and time for the patient (1, 2, 11, 42, 44).

Several different clinical situations have been identified as possible cofactors in the etiopathogenesis of this clinical situation:

- insufficient soft-tissue healing after tooth extraction
- improper flap design
- insufficient flap release
- suturing under tension
- compression from the removable provisional prosthesis.

Treatment

The treatment of a premature membrane exposure depends on the presence or absence of a purulent exudate and on the extent of the soft-tissue dehiscence.

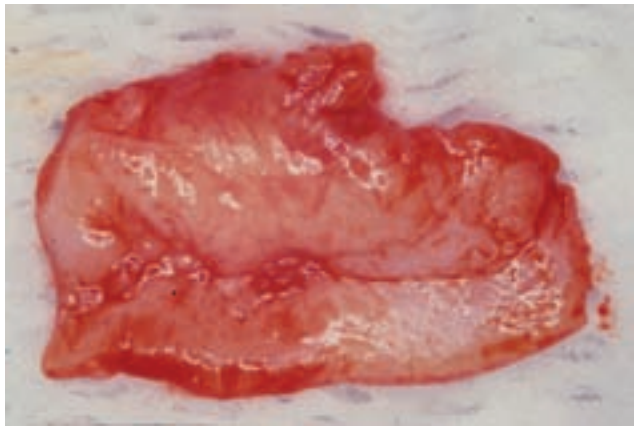


Fig. 14.31 A connective tissue graft is taken from the palate.

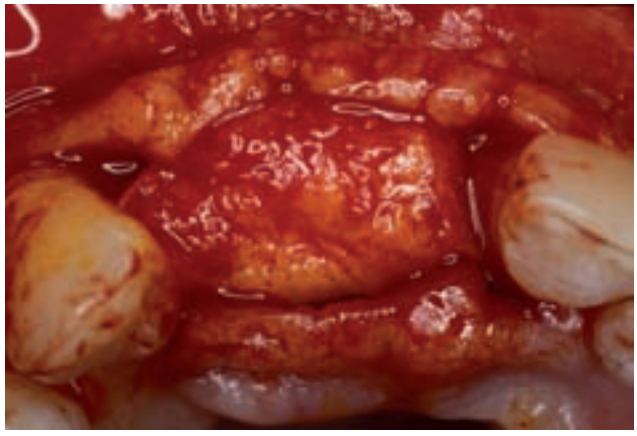


Fig. 14.32 The connective tissue is placed on the regenerating area acting as a barrier to protect the healing of the underlying tissue.

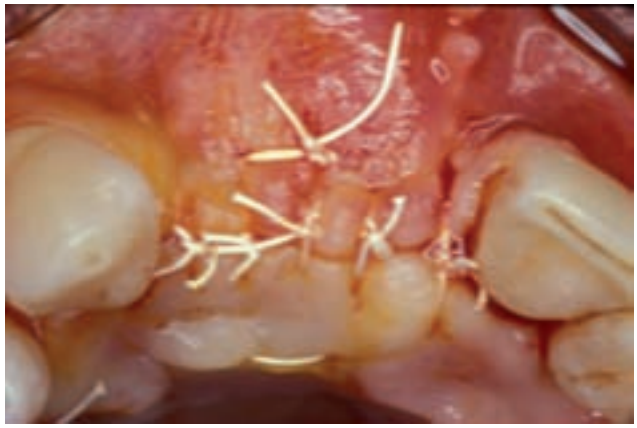


Fig. 14.33 The buccal and lingual flaps are sutured with horizontal mattress suture and single interrupted stitches.

Class I and II: Membrane exposure without purulent exudate

Case 1 (Figs 14.28–14.33)

In class I cases with a fenestration smaller than 3 mm, the exposure can be maintained with a focussed hygiene regimen consisting of topical application of 0.2% chlorhexidine gel twice a day to reduce plaque formation and avoid inflammation of the surrounding tissues. The membrane can be left in place for a maximum of 3–4 weeks. Nevertheless, a weekly follow-up of the patient is necessary. After this period, membrane removal must be performed. Because of its osteogenic potential, the soft tissue under the membrane must not be removed, to avoid damage to the regenerating tissue. A small soft-tissue fenestration can also be treated by removing the exposed portion of the membrane and by flap closure of the dehisced area (Figs 14.28–14.31). A connective tissue graft should be placed into the opening to protect the healing of the underlying regenerating bone (Figs 14.32, 14.33).

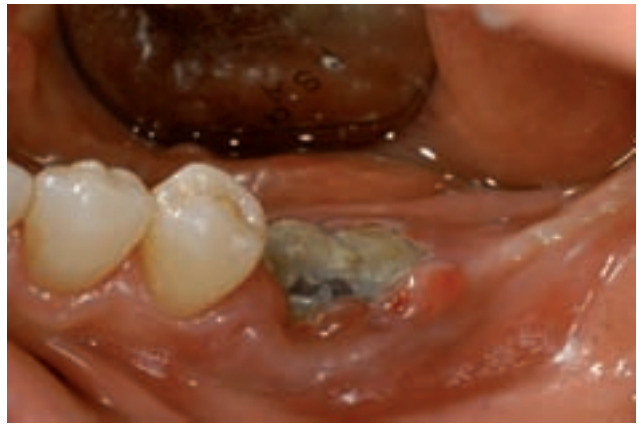


Fig. 14.34 A wide premature exposure of an e-PTFE membrane without purulent exudation, 3 months after the surgery. Note the inflammation of the soft tissue and the deposit of calculus on the exposed membrane.

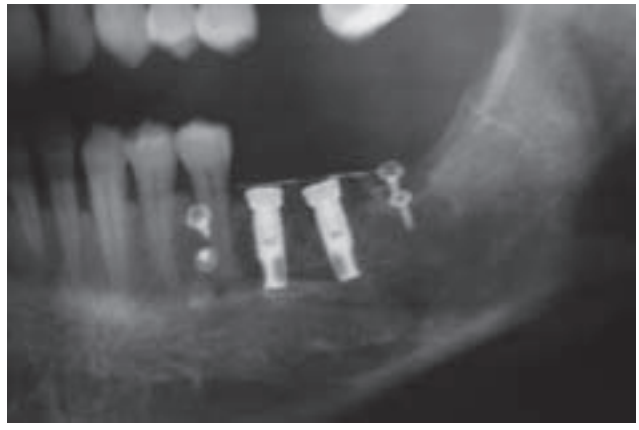


Fig. 14.35 Orthopantomogram before membrane removal, showing the area regenerating by means of the guided bone regeneration technique.

Case 2 (Figs 14.34–14.40)
In cases exhibiting an exposure larger then 3 mm (class II), the membrane must immediately be removed to avoid infection of the regenerating tissue (Figs 14.34–14.40). If the underlying bone graft is not compromised, the flaps should be closed to allow the grafted area to heal for at least 4–5 months. Antibiotics coverage with amoxicillin and clavulanic acid is also suggested.

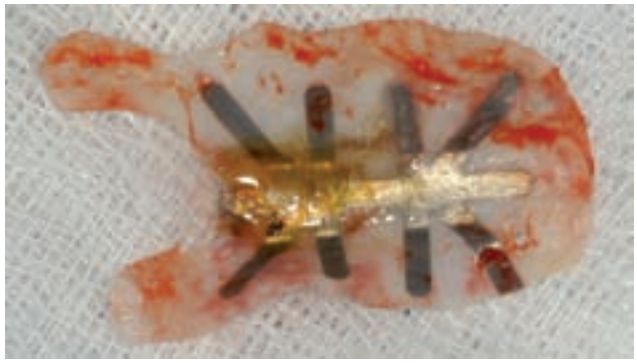


Fig. 14.36 The e-PTFE membrane removed. Note the yellow–brown color of the part of the membrane exposed to the oral environment.

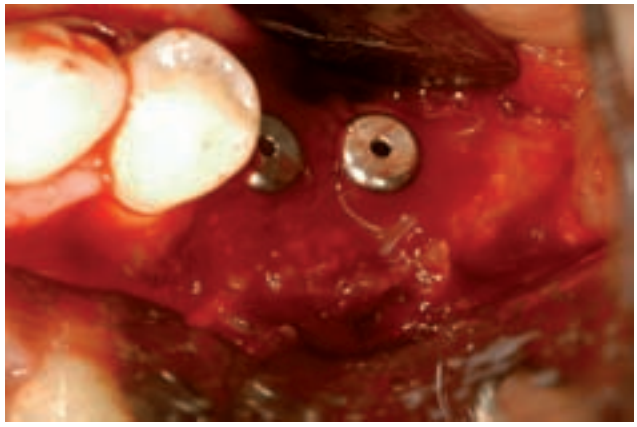


Fig. 14.37 After membrane removal, highly vascularized and inflamed tissue is present. The buccal part of the regenerating area has been replaced by granulating tissue. It is gently removed so as not to jeopardize the hole area.

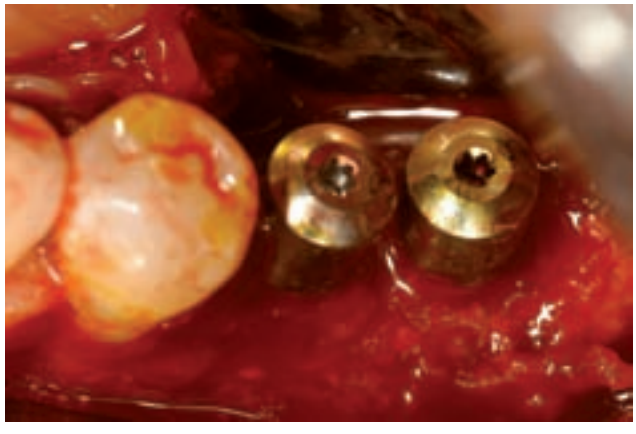


Fig. 14.38 The implants are stable, so two healing abutments are connected.

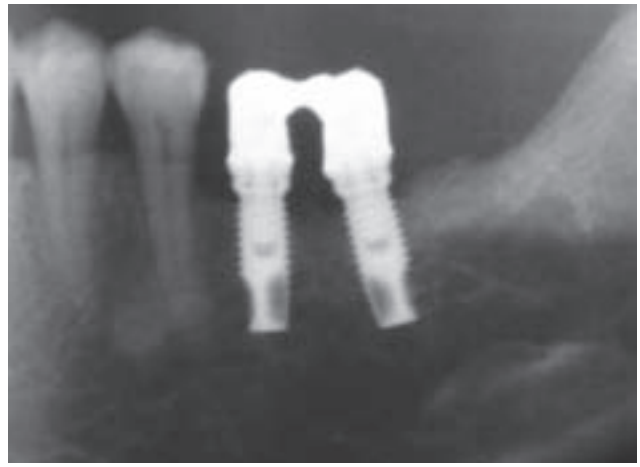


Fig. 14.39 Orthopantomogram showing implants 36 and 37 at the time of temporary crown positioning, 1 month after membrane removal. A little bone loss in the vertical dimension is the consequence of the premature membrane exposure.

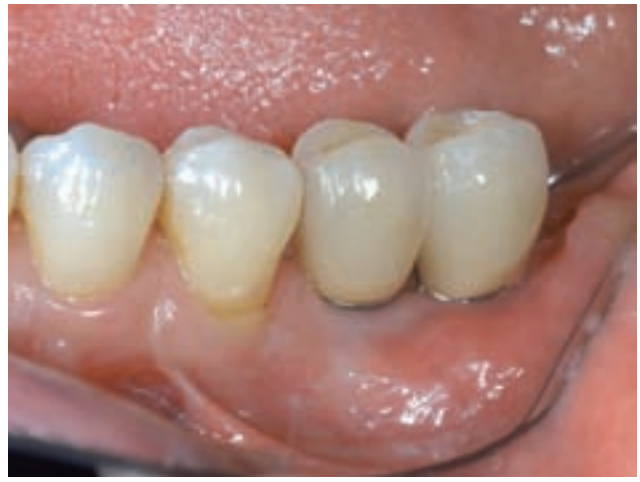


Fig. 14.40 Lateral view of the final restoration 4 months after membrane removal. The soft tissue has a healthy appearance.

Class III: Membrane exposure with purulent exudate

If the membrane exposure is associated with a purulent exudate, the membrane must be removed immediately to limit the damage caused by the infection spreading to the underlying regenerating tissue. After membrane removal, a gentle curettage of the graft is essential to remove the infected particles and inflammatory tissue that could jeopardize the regenerative process. Amoxicillin (875 mg) and clavulanic acid (125 mg) (Augmentin; GlaxoSmithKline) should be prescribed twice a day for at least 5 days.

Key points to avoid membrane exposure:

- *Healing of the soft tissues*: A complete healing of the soft tissue before any GBR procedure is fundamental for a successful outcome of the technique. The soft tissue must be healthy and well keratinized without

any signs of inflammation. These factors allow a proper flap design, optimal suturing technique and primary soft-tissue healing. If tooth extraction has been performed, an 8–10 week soft-tissue healing period is recommended before any GBR procedure is performed.

- *Flap design and meticulous recipient site preparation*: As reported in the previous section, Prevention of complications, the flap must be properly designed to achieve a tension-free suture closure to complete the surgery.
- *Releasing periosteal incisions*: A horizontal continuous periosteal incision of the buccal flap is necessary. The buccal and lingual/palatal flaps should overlap by at least 10 mm to obtain a tension-free closure. Tension leads to ischemia of the tissue adjacent to the sutures with subsequent necrosis and membrane dehiscence.
- *Suturing technique*: A suitable suturing technique is essential for successful healing. Flaps are sutured with two lines of closure: first, internal horizontal mattress sutures are used to obtain proper flap apposition, and then single interrupted sutures to close the space between the horizontal mattress and the vertical incisions.
- *Adequate provisional prosthesis*: A fixed provisional prosthesis is always preferred when performing a GBR procedure. A removable prosthesis should not be used within 15–20 days after any GBR procedure. Following that period, the removable prosthesis must be adjusted to avoid any pressure and movement to the underlying soft tissue. Compression during the early healing period always leads to ischemia, flap necrosis and subsequent membrane exposure. When a vertical ridge augmentation has been performed, any removable prosthesis must not be worn for the entire healing period.

Class IV: Abscess formation without membrane exposure

Case 3 (Figs 14.41–14.46)

This is a rare, albeit severe clinical complication, characterized by the formation of an abscess in the surgical area without the exposure of the membrane. When this occurs, the abscess usually forms within the first 3–4 weeks postoperatively. The surgical area contains swollen, inflamed tissue with pus formation. Pain, tension, increased temperature and fistula formation may also be reported.

The etiopathogenesis of this phenomenon may include any one or more of the following:

- bacterial contamination of the e-PTFE during membrane handling
- bacterial contamination of the bone graft
- improper suture removal

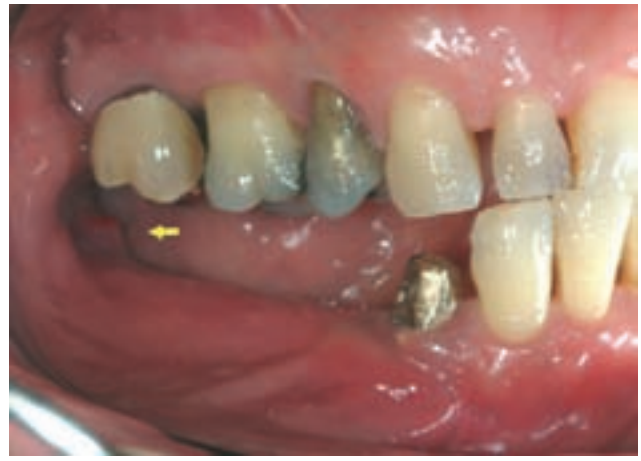


Fig. 14.41 An abscess formed in posterior right mandible where a vertical ridge augmentation by means of guided bone regeneration had been performed 3 weeks before. The area is swollen and red, and the patient reports pain and tension. A fistula can also be observed in the retromolar area (yellow arrow).

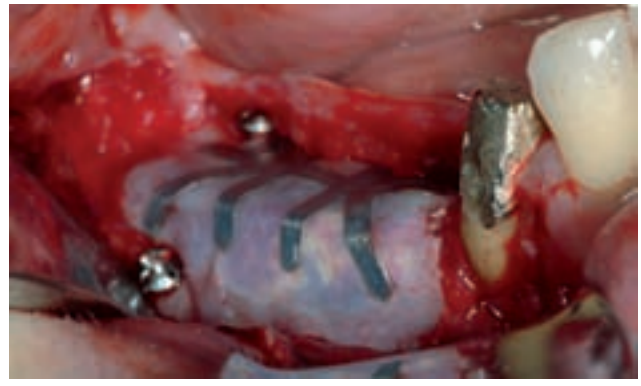


Fig. 14.42 Two full-thickness flaps are elevated to remove the membrane and the fixation devices. A yellow area of pus can be observed through the membrane.

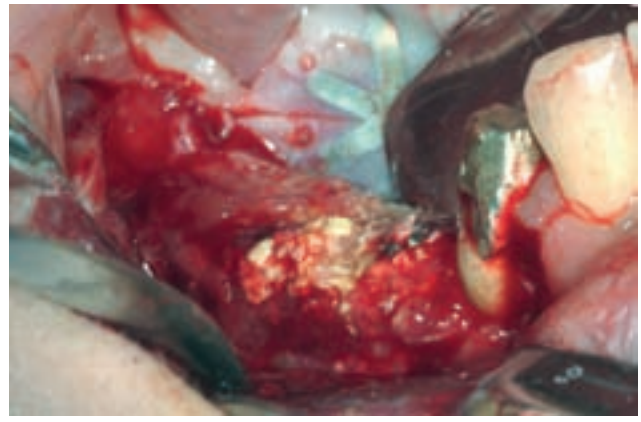


Fig. 14.43 Under the membrane, an infected and hyperemic tissue can be detected. All the regenerating area must be removed to eliminate the infection.

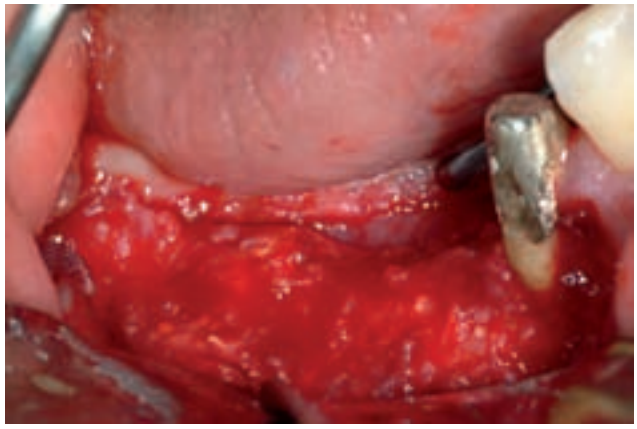


Fig. 14.44 The residual crest after curettage of the area and washing with rifamycin solution.

- endodontic/periodontic infections from adjacent teeth
- inadequate prosthetic margins
- patient inoculation of the area with exogenous bacteria (e.g. hands, nails, toothbrushes, removable provisionals).

Treatment

The membrane must be immediately removed and all the infected tissue curetted. The use of a rifamycin (Rifocin 90 mg; Sanofi Aventis) or tetracycline (Ambramicina 250 mg; Scharper) antibiotic wash is also suggested to reduce bacterial contamination of the treated area. The patient should be placed on a regimen of amoxicillin (875 mg) and clavulanic acid (125 mg) twice daily (Augmentin) for at least 5 days.

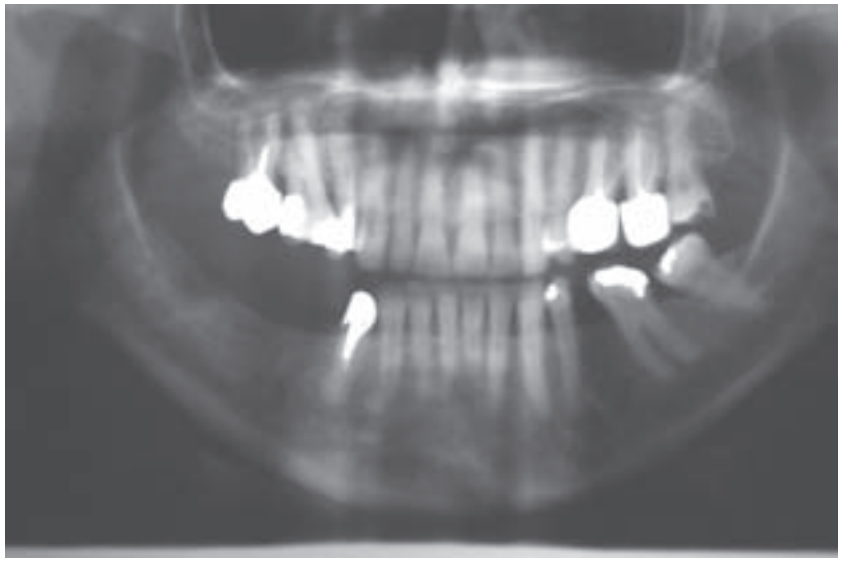


Fig. 14.45 Orthopantomogram showing the edentulous area (lower right) before the guided bone regeneration procedure.

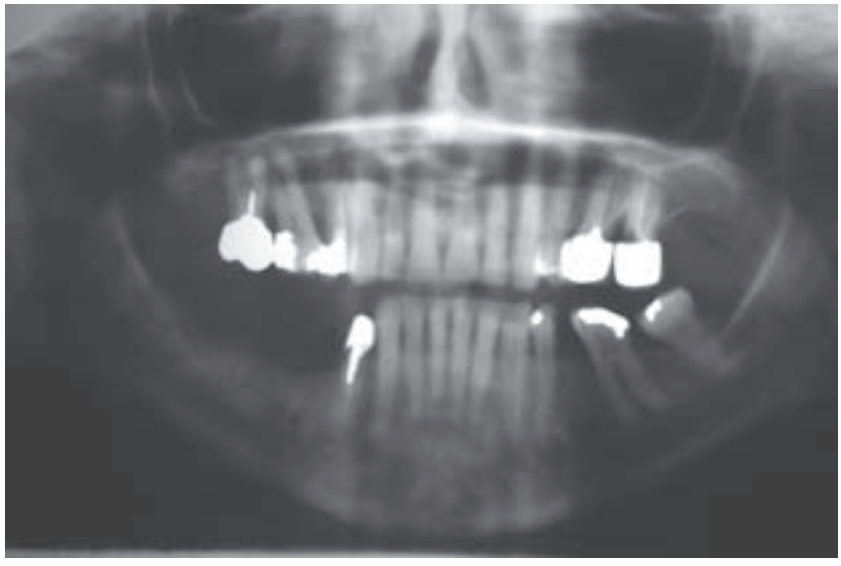


Fig. 14.46 Orthopantomogram showing the edentulous area (lower right) after the abscess formation and membrane removal. Note that the residual defect after the complication occurred is more significant then the baseline defect.

Case 4 (Figs 14.47–14.53)

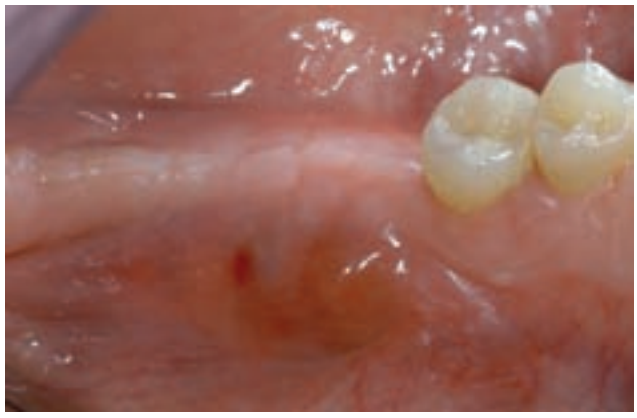


Fig. 14.47 A lingual abscess without membrane exposure occurred 5 weeks after guided bone regeneration; a titanium-reinforced e-PTFE membrane was applied simultaneously with implant insertion.

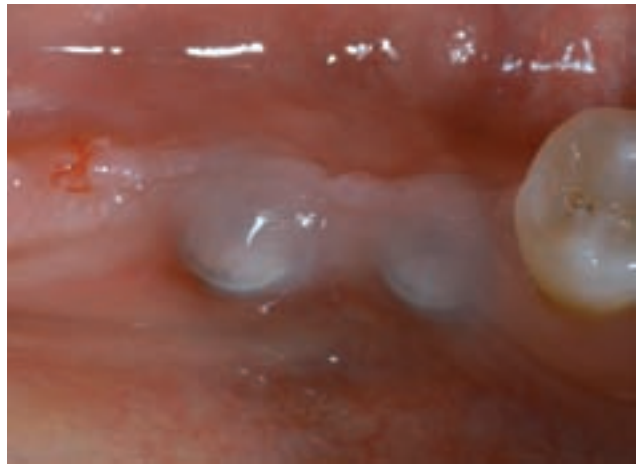


Fig. 14.50 Lingual aspect of Fig. 14.49. A bone defect is evident in correspondence to the area of the previous curettage of the granulating tissue. The soft tissue is extremely thin but still integral. A successive guided bone regeneration with a reabsorbable membrane was planned to achieve the result.

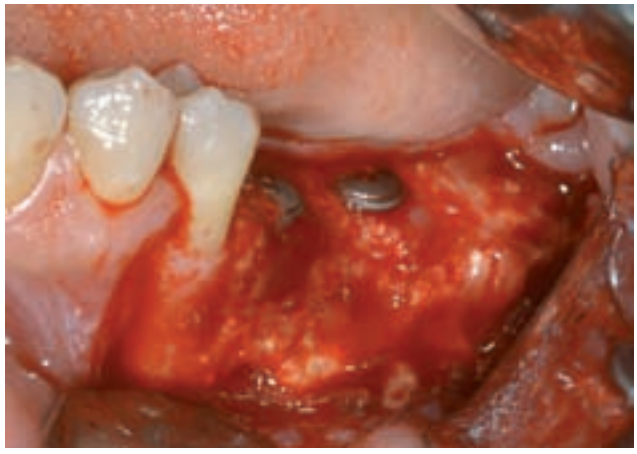


Fig. 14.48 After flap elevation and membrane removal, gentle curettage of the inflamed tissue was performed at the lingual aspect of the two implants and at the buccal part of implant 36. Most of the bone graft looked healthy and therefore was left in place.

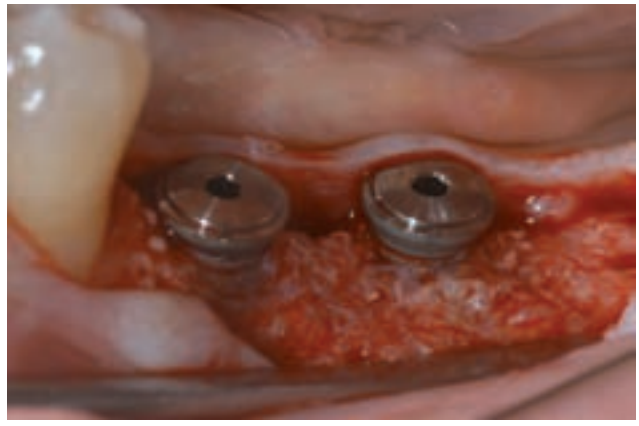


Fig. 14.51 Two full-thickness flaps were elevated to expose the area to regenerate.

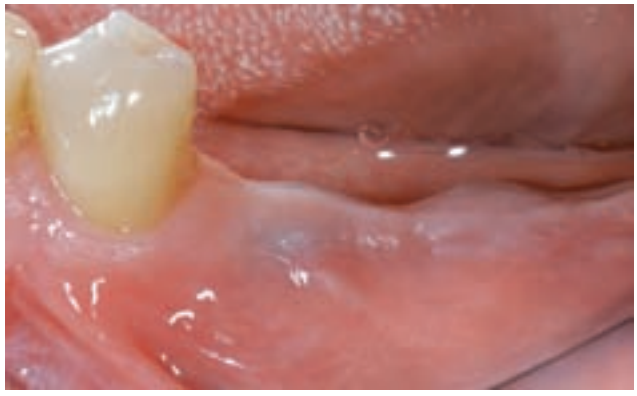


Fig. 14.49 Buccal view. The regenerating area was left to heal for an additional 4 months.

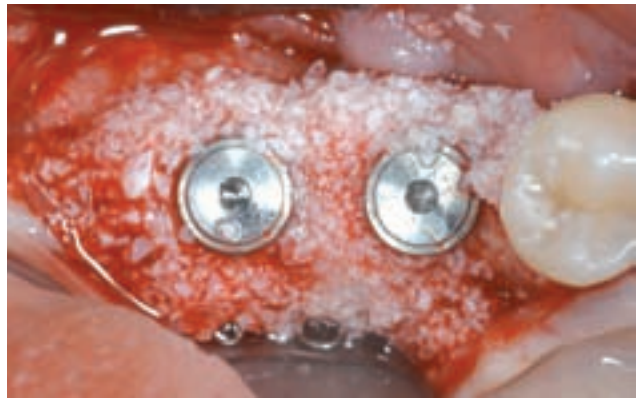


Fig. 14.52 A xenograft (Bio-Oss) was packed to fill the empty space around the two partially exposed implants.

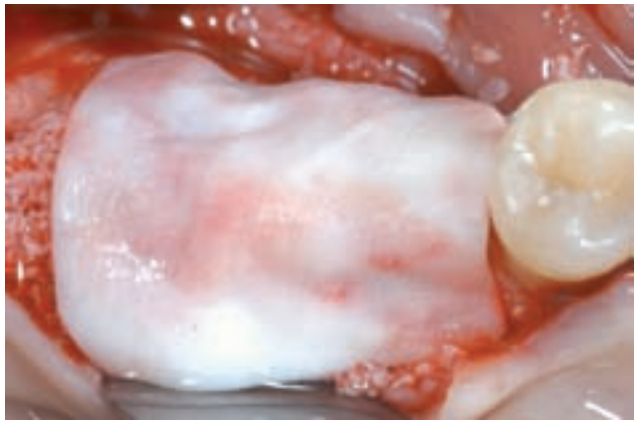


Fig. 14.53 A reabsorbable collagen membrane was adapted over the bone graft.

Key points to avoid abscess formation:

- *e-PTFE membrane*: Particular care must be taken to reduce the risk of bacterial colonization of the surface of the non-absorbable e-PTFE membrane. Presurgical preparation of the patient should consist of all necessary periodontal treatment, full mouth disinfection with chlorhexidine digluconate 0.2% mouthrinse (Corsodyl; GlaxoSmithKline) and an extraoral scrub with a povidone–iodine solution (Betadine; Viatris). Moreover, the membrane must be kept in a sterile field and the surgeon must wear new sterile gloves before membrane handling, since the first part of the surgery could cause bacterial contamination of the surgical gloves.
- *Autogenous bone graft harvesting procedure*: Recently, a systematic review by the Cochrane Library (11) stated that: "The use of particulated autogenous bone from intraoral locations might be associated with an increased risk of infective complications…." Particular care must be taken to avoid contamination of the harvested bone with saliva. The authors suggest collecting bone with a bone scraper or trephine bur under abundant irrigation with saline solution. The use of bone traps, also with dedicated suction tubes, is not advisable because considerable amounts of bacteria can be found in particulated bone collected with these devices (45).
- *Suture removal*: During the first 2 weeks of healing, the horizontal mattress sutures tend to invaginate into the soft tissue. Thus, suture removal may be difficult and require local anesthesia. Non-absorbable sutures should be removed within this period. If left in the tissue they may cause granuloma and abscess formation.
- *Remove all sources of infection*: Every possible source of endodontic or periodontic infection must be removed before performing a GBR procedure. For the same reason any inadequate restorations or restorative margins on teeth adjacent to the area planned for regeneration must be corrected or reconstructed before the surgery.

Lesions associated with periosteal incisions

One of the key steps in the GBR technique is adequate release of buccal and lingual flaps to ensure tension-free suture closure. This procedure includes the incision of the buccal periosteum in both the lower and upper jaw. In the lingual aspect of the mandible, release of the periosteum is performed by reflecting the flap beyond the insertion of the mylohyoid muscle.

In the mandible, particular care should be taken to avoid any damage to the inferior alveolar nerve at its exit from the mental foramen. The same care should be taken in the upper jaw with the infraorbitary nerve. Improper procedures can cause temporary or permanent sensory effects (anesthesia, paresthesia, or dyesthesia).

Moreover, surgical trauma to the lingual flap can lead to edema of the sublingual space (over the mylohyoid muscle) and of the submandibular space (under the mylohyoid muscle). These areas are susceptible to space infections which may be serious and require emergency medical treatment.

Key points to prevent these complications:

- Be aware and locate (radiographically and clinically) the anterior loop of the mental nerve.
- The buccal periosteal incision must be performed at a distance which is at least 4–5 mm away from the mental foramen and must be very superficial, as a deep incision could damage the mental nerve (Fig. 14.5).
- Avoid any incision of the lingual periosteum. The lingual flap must be managed with care because of its proximity to the floor of the mouth, which represents one of the most critical areas when performing GBR. Apical to the floor of the mouth is the sublingual space. The sublingual space is the area between the mylohyoid muscle, the mandible, and the geniohyoid and genioglossal muscles, containing important anatomic structures, such as the sublingual artery (branch of the lingual artery), the mylohyoideus artery (branch of the inferior alveolar artery), the lingual nerve, Wharton's duct, the sublingual gland, and some extrinsic tongue muscle fibers. To minimize postoperative edema and hemorrhage and to avoid any damage to these anatomic structures incision of the lingual periosteum should be avoided when not strictly necessary for release of the tissue (Fig. 14.6).
- In all cases a thorough knowledge of oral anatomy is essential for any clinician performing these procedures.

Conclusion

Although the GBR technique is considered to be a predictable surgical procedure, further modifications in materials and techniques are being studied to reduce clinical complications. Adherence to proven clinical protocol and the introduction of new materials could reduce the incidence of complications and increase the predictability of bone augmentation.

The clinical protocols related to the GBR technique, including surgical procedures, postoperative care, and healing time, were established using non-absorbable membranes. However, the use of absorbable membranes is increasing owing to their proven effectiveness and user-friendly properties, limiting e-PTFE membranes to specific indications.

Take-home hints

- Allow adequate healing of the soft tissue before performing a GBR procedure.
- Remove all sources of infection before surgery (i.e. periodontally, endodontally, or hopelessly involved teeth).
- Design the flap to ensure adequate blood supply and flap closure.
- Meticulous recipient site preparation is essential.
- Clearly locate (radiographically and clinically) important adjacent anatomic structures.
- Ensure adequate release of the buccal flap with a periosteal incision.
- Ensure appropriate membrane positioning and fixation.
- Suturing technique is important: first use internal horizontal mattress sutures, and then single interrupted sutures.
- Adequate presurgical and postsurgical care includes systemic antibiotics and local antiseptics.
- Adequate knowledge is required regarding oral anatomy and the prevention and treatment of complications.

References

1. Buser D, Dula K, Belser U, Hirt HP, Berthold H. Localized ridge augmentation using guided bone regeneration. I. Surgical procedure in the maxilla. *Int J Periodontics Restorative Dent* 1993; **13**: 29–45.
2. Buser D, Dula K, Belser U, *et al.* Localized ridge augmentation using guided bone regeneration. II. Surgical procedure in the mandible. *Int J Periodontics Restorative Dent* 1995; **15**: 10–29.
3. Dahlin C, Linde A, Gottlow J, *et al.* Healing of bone defects by guided tissue regeneration. *Plast Reconstr Surg* 1988; **81**: 672–6.
4. Dahlin C, Sennerby L, Lekholm U, *et al.* Generation of new bone around titanium implants using a membrane technique: an experimental study in rabbits. *Int J Oral Maxillofac Implants* 1989; **4**: 19–25.
5. Nyman S, Gottlow J, Karring T, *et al.* The regenerative potential of the periodontal ligament. An experimental study in the monkey. *J Clin Periodontol* 1982; **9**: 257–65.
6. Gottlow J, Nyman S, Karring T, *et al.* New attachment formation as the result of controlled tissue regeneration. *J Clin Periodontol* 1984; **11**: 494–503.
7. Gottlow J, Karring T, Nyman S. Guided tissue regeneration following treatment of recession-type defects in the monkey. *J Periodontol* 1990; **61**: 680–5.
8. Gottlow J, Nyman S, Karring T, *et al.* New attachment formation as the result of controlled tissue regeneration. *J Clin Periodontol* 1984; **11**: 494–503.
9. Gottlow J, Nyman S, Lindhe J, *et al.* New attachment formation in the human periodontium by guided tissue regeneration. Case reports. *J Clin Periodontol* 1986; **13**: 604–16.
10. Rocchietta I, Fontana F, Simion M. Clinical outcomes of vertical bone augmentation to enable dental implant placement. A systematic review. *J Clin Periodontol* 2008; **35** (8 Suppl): 203–15.
11. Esposito M, Grusovin MG, Worthington HV, *et al.* Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment. *Cochrane Database Syst Rev* 2006; Issue 1.
12. Verardi S, Simion M. Management of the exposure of e-PTFE membranes in guided bone regeneration. *Pract Proced Aesthet Dent* 2007; **19**: 111–17.
13. Buser D, Bragger U, Lang NP, *et al.* Regeneration and enlargement of jaw bone using guided tissue regeneration. *Clin Oral Implants Res* 1990; **1**: 22–32
14. Buser D, Dula K, Hirt HP, *et al.* Lateral ridge augmentation using autografts and barrier membranes: a clinical study with 40 partially edentulous patients. *J Oral Maxillofac Surg* 1996; **54**: 420–32; Discussion 432–3.
15. Tinti C, Parma-Benfenati S, Polizzi G. Vertical ridge augmentation: what is the limit? *Int J Periodontics Restorative Dent* 1996; **16**: 221–9.
16. Simion M, Jovanovic SA, Trisi P, *et al.* Vertical ridge augmentation around dental implants using a membrane technique and autogenous bone or allografts in humans. *Int J Periodontics Restorative Dent* 1998; **18**: 8–23.
17. Simion M, Fontana F, Rasperini G, *et al.* Long-term evaluation of osseointegrated implants placed in sites augmented with sinus floor elevation associated with vertical ridge augmentation: a retrospective study of 38 consecutive implants with 1- to 7-year follow-up. *Int J Periodontics Restorative Dent* 2004; **24**: 208–21.
18. Simion M, Fontana F, Rasperini G, *et al.* Vertical ridge augmentation by expanded-polytetrafluoroethylene membrane and a combination of intraoral autogenous bone graft and deproteinized anorganic bovine bone (Bio-Oss). *Clin Oral Implants Res* 2007; **18**: 620–629.
19. Merli M, Migani M, Esposito M. Vertical ridge augmentation with autogenous bone grafts: resorbable barriers sup-

ported by ostheosynthesis plates versus titanium-reinforced barriers. A preliminary report of a blinded, randomized controlled clinical trial. *Int J Oral Maxillofac Implants* 2007; **22**: 373–82.
20. Fontana F, Santoro F, Maiorana C, *et al.* Clinical and histological evaluation of allogenous bone matrix versus autogenous bone chips associated with titanium reinforced e-PTFE membrane for vertical ridge augmentation: a prospective pilot study in the human. *Int J Oral Maxillofac Implants* 2008; **23**: 1003–12.
21. Simion M, Baldoni M, Rossi P, *et al.* A comparative study of the effectiveness of e-PTFE membranes with and without early exposure during the healing period. *Int J Periodontics Restorative Dent* 1994; **14**: 166–80.
22. Simion M, Trisi P, Maglione M, *et al.* A preliminary report on a method for studying the permeability of expanded polytetrafluoroethylene membrane to bacteria *in vitro*: a scanning electron microscopic and histological study. *J Periodontol* 1994; **65**: 755–61.
23. Simion M, Trisi P, Maglione M, *et al.* Bacterial penetration *in vitro* through GTAM membrane with and without topical chlorhexidine application. A light and scanning electron microscopic study. *J Clin Periodontol* 1995; **22**: 321–31.
24. Schenk RK, Buser D, Hardwick WR, *et al.* Healing pattern of bone regeneration in membrane-protected defects: a histologic study in the canine mandible. *Int J Oral Maxillofac Implants* 1994; **9**: 13–29.
25. Tinti C, Parma-Benfenati S. Vertical ridge augmentation: surgical protocol and retrospective evaluation of 48 consecutively inserted implants. *Int J Periodontics Restorative Dent* 1998; **18**: 434–43.
26. Parma-Benfenati S, Tinti C, Albrektsson T, *et al.* Histologic evaluation of guided vertical ridge augmentation around implants in humans. *Int J Periodontics Restorative Dent* 1999; **19**: 424–37.
27. Burchardt H. The biology of bone graft repair. *Clin Orthop Relat Res* 1983; **174**: 28–42.
28. Tidwell JK, Blijdorp PA, Stoelinga PJ, *et al.* Composite grafting of the maxillary sinus for placement of endosteal implants: a preliminary report of 48 patients. *Int J Oral Maxillofac Surg* 1992; **21**: 204–9.
29. Misch CE, Dietsh F. Bone grafting materials in implant dentistry. *Implant Dent* 1993; **2**: 158–67.
30. Yildirim M, Spiekermann H, Handt S, *et al.* Maxillary sinus augmentation with the xenograft Bio-Oss and autogenous intraoral bone for qualitative improvement of the implant site: a histologic and histomorphometric clinical study in humans. *Int J Oral Maxillofac Implants* 2001; **16**: 23–33.
31. Simion M, Jovanovic SA, Tinti C, *et al.* Long-term evaluation of osseointegrated implants inserted at the time or after vertical ridge augmentation. A retrospective study on 123 implants with 1–5 year follow-up. *Clin Oral Implants Res* 2001; **12**: 35–45.
32. Zitzmann NU, Naef R, Scharer P. Resorbable versus nonresorbable membranes in combination with Bio-Oss for guided bone regeneration. *Int J Oral Maxillofac Implants* 1998; **13**: 576.
33. Zitzmann NU, Scharer P, Marinello CP. Long-term results of implants treated with guided bone regeneration: a 5-year prospective study. *Int J Oral Maxillofac Implants* 2001; **16**: 355–66.
34. Fugazzotto PA. GBR using bovine bone matrix and resorbable and nonresorbable membranes. Part 1: Histologic results. *Int J Periodontics Restorative Dent* 2003; 23: 361–9.
35. Fugazzotto PA. GBR using bovine bone matrix and resorbable and nonresorbable membranes. Part 2: Clinical results. *Int J Periodontics Restorative Dent* 2003; **23**: 599–605.
36. Canullo L, Trisi P, Simion M. Vertical ridge augmentation around implants using e-PTFE titanium-reinforced membrane and deproteinized bovine bone mineral (Bio-Oss): a case report. *Int J Periodontics Restorative Dent* 2006; **26**: 355–61.
37. Becker W, Becker BE. Guided tissue regeneration for implants placed into extraction sockets and for implant dehiscences: surgical techniques and case report. *Int J Periodontics Restorative Dent* 1990; **10**: 376–91.
38. Dahlin C, Simion M, Nanmark U, *et al.* Histological morphology of the e-PTFE/tissue interface in humans subjected to guided bone regeneration in conjunction with oral implant treatment. *Clin Oral Implants Res* 1998; **9**: 100–6.
39. Gotfredsen K, Nimb L, Buser D, *et al.* Evaluation of guided bone regeneration around implants placed into fresh extraction sockets. An experimental study in dogs. *J Oral Maxillofac Surg* 1993; **51**: 879–84.
40. Lekholm U, Becker W, Dahlin C, *et al.* The role of early versus late removal of GTAM membranes on bone formation at oral implants placed into immediate extraction sockets. An experimental study in dogs. *Clin Oral Implants Res* 1993; **4**: 121–9.
41. Kohal RJ, Trejo PM, Wirsching C, *et al.* Comparison of bioabsorbable and bioinert membranes for guided bone regeneration around non-submerged implants. An experimental study in the mongrel dog. *Clin Oral Implants Res* 1999; **10**: 226–37.
42. Jovanovic SA, Spiekermann H, Richter EJ. Bone regeneration around titanium dental implants in dehisced defect sites: a clinical study. *Int J Oral Maxillofac Implants* 1992; **7**: 233–45.
43. Becker W, Dahlin C, Becker BE, *et al.* The use of e-PTFE barrier membranes for bone promotion around titanium implants placed into extraction sockets: a prospective multicenter study. *Int J Oral Maxillofac Implants* 1994; **9**: 31–40.
44. Simion M, Trisi P, Piattelli A. Vertical ridge augmentation using a membrane technique associated with osseointegrated implants. *Int J Periodontics Restorative Dent* 1994; **14**: 496–511.
45. Young MP, Carter DH, Worthington H, *et al.* Microbial analysis of bone collected during implant surgery: a clinical and laboratory study. *Clin Oral Implants Res* 2001; **12**: 95–103.

Chapter 15

Avoiding complications for alveolar distraction osteogenesis and osteoperiosteal flaps

Ole T. Jensen DDS, MS

Introduction

Complications related to augmentation for alveolar width and height by distraction osteogenesis, alveolar ridge split, or interpositional grafting have their etiology and prevention within the diagnostic treatment plan. Without an adequate diagnosis and treatment plan complications are likely to occur.

The purpose of this chapter is to discuss diagnostic, technical, and medical management of complicating factors in the treatment of alveolar deficiency.

It is understood that clinicians are familiar enough with the described procedures to skip forward to complications, their etiology, prevention, and treatment.

Alveolar distraction osteogenesis

Alveolar distraction osteogenesis is a segmental osteotomy procedure that when slowly moved over time regenerates bone in the widening interpositional gap. The technique is best used in the esthetic zone and most commonly for alveolar vertical defects of 10 mm or more. The technique when done improperly can lead to complete loss of the segment from vascular embarrassment.

Alveolar distraction is done through a vestibular incision where a vestibular 5 mm horizontal osteotomy is connected to vertical osteotomies to create a segmental osteotomy for alveolar elevation once attached to a distraction device (Figs 15.1–15.3). Distraction begins after a latency period of 1 week and then proceeds at 0.5–0.8 mm/day until completed. A 4-month consolidation period is recommended.

Complication: vascular embarrassment of segmental osteotomy

Etiology

The complete stripping of vascular blood supply from a mobilized osteotomy segment will cause necrosis and the entire loss of that segment including bone and soft tissue. Partial stripping will cause a partial loss of the segment leading to reductive remodeling over the ensuing postoperative year. Even overstretching or cutback releasing incisions probably reduce the viability of the mobilized segment. Therefore, a vestibular approach with minimal flapping for device placement and osteotomy access is recommended.

Prevention

When an alveolus is of sufficient bone mass and axially aligned into class I arch relation, the alveolus is said to be in orthoalveolar form. This conceptual criterion is used to diagnose and establish corrected hard- and soft-tissue morphology on models. When this is done the extent of the alveolar defect is better understood. Appropriate preoperative planning is the best way to prevent intraoperative calamity. This is especially true for distraction osteogenesis which must be targeted to a planned goal. An esthetic control model (Fig. 15.4) based on mounted study casts and a diagnostic wax-up is created from which all subsequent treatment is predicated. The deficient alveolus is thereby corrected for width and height as well as class I interarch relation to recover orthoalveolar form.

Diagnostic procedures

Computer axial tomographic (CAT) scan images are done to provide a cross-sectional view of bone quantity and bone quality (via Hounsfield units), and to rule out

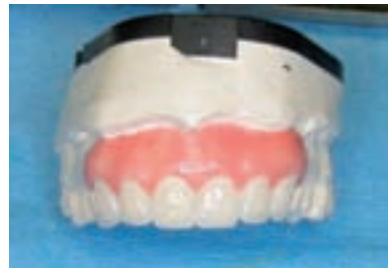
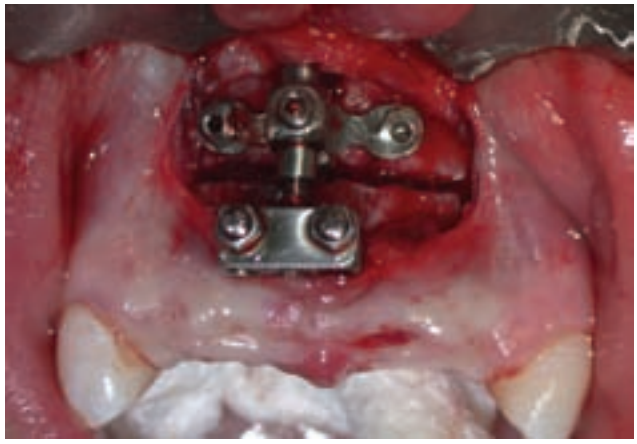
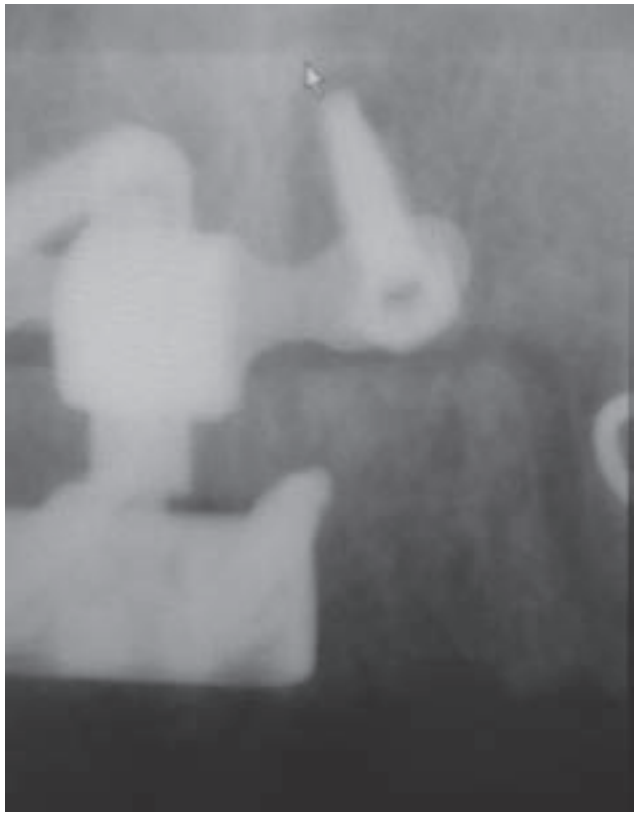


Fig. 15.1 A segmental osteotomy is done through a vestibular incision with no attempt to reflect the mucoperiostium crestally.





Figs 15.2, 15.3 Following osteotomy the distraction device is applied and then distracted after a 1-week latency period.

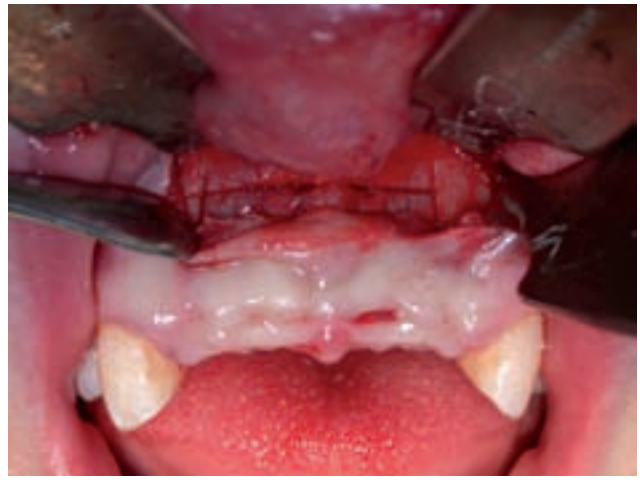


Fig. 15.4 An esthetic control model established the goal of distraction osteogenesis which is orthoalveolar form.

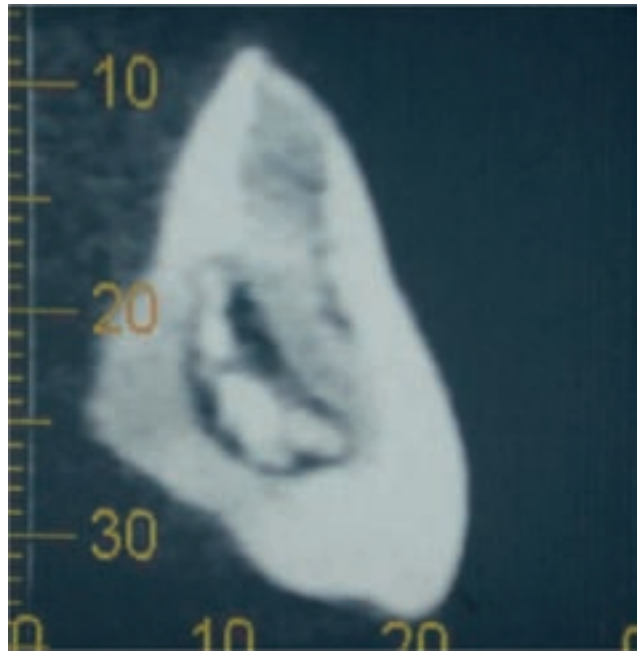


Fig. 15.5 A CAT scan provides information about bone quality, quantity, and pathology. The CAT scan image demonstrates medullary osteomylitis.

the presence of intra-alveolar defects or pathology (Figs 15.5, 15.6). The scan, when done with a prosthetic stent showing tooth position, and desired implant sites, can tell the surgeon how much bone mass is required to bring the deficient jaw into orthoalveolar form. If a complication occurs, that of loss or partial loss of a segment of bone, this is easily quantified by comparing to the preoperative esthetic control model.

Articulated casts

The use of articulated casts for a diagnostic wax-up is even more important than radiographic images. Tooth positions are established and the guide stent is made from this wax-up so that when the guide is positioned on the original model, angulations and alveolar defects are easily observed (Figs 15.7, 15.8). The guide stent, when placed for CAT scan imaging, precisely demarcates bone volume determinates. A well-made surgical template probably helps prevent complication better than any single treatment criterion.

Treatment plan

A treatment plan is best designed by both surgical and prosthodontic disciplines. Though single-operator

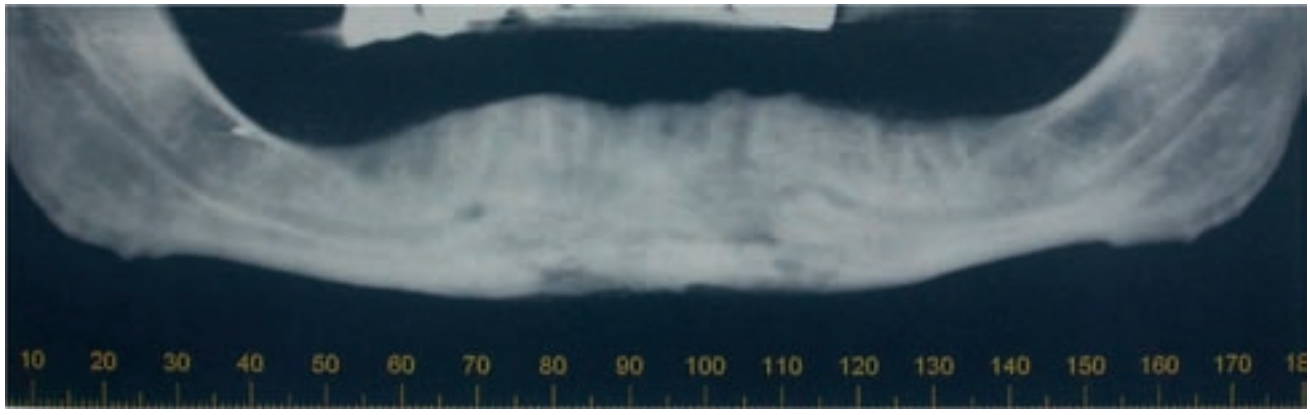


Fig. 15.6 A CAT scan reconstruction of the panographic view shows an osteomyolitic lesion in the area where implants are desired.

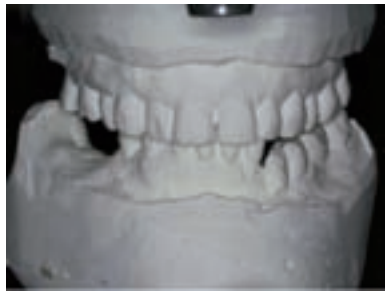


Fig. 15.7 Study models help elucidate alveolar defects.

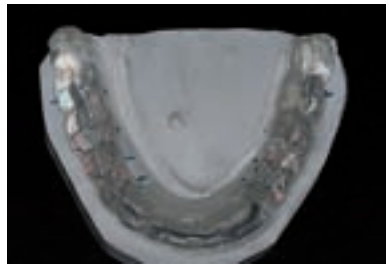


Fig. 15.8 A guide stent when placed at the time of CAT scan imaging precisely demarcates bone volume determinates.

responsibility can be successful, the results, when judged critically, are often limited by inadequate skill or expertise in one discipline or the other.

An optimized treatment plan requires both experienced surgical and dental restorative mindsets. Knowing what is achievable in hard- and soft-tissue reconstruction must complement what is biomechanically and esthetically required by the restorative plan.

Treatment complications of alveolar augmentation procedures are most often avoided by appropriate collaboration of a well thought-out treatment plan. Once a collaborative treatment plan has been determined, surgical procedures are proposed to the patient for approval, and include a discussion of risks and benefits of the procedure.

Vertical alveolar distraction is generally used for vertical defects of 6 mm or more. Most frequently the bone transported is a two- to four-tooth segment. At first, osteogenesis proceeds away from the access wound due to the mucoperiosteal reflection. Therefore, care should be taken to not disturb the lingual or palatal pedicle as well as minimize the amount of buccal mucoperiosteal reflection. There are two reasons for this: to avoid vascular embarrassment of the transport segment, and to leave intact as much functional periostium for osteogenesis as is possible. Techniques that perform palatal releasing incisions or full facial reflection of the periosteum risk transport viability leading to late remodeling resorption. For this reason, small segments, such as one-tooth segments, should be avoided as flap detachment is more likely to occur during segment manipulation. A torn or detached flap or fracture of a small segment considerably diminishes osseous healing capacity (1).

Treatment

Should a segmental osteotomy be completely lost, a tibial or iliac graft is usually needed to restore bone mass. Bone morphogenetic protein-2 (BMP-2) is another alternative, though at present an off-label use. The treatment of partially resorbed segments is even more difficult for, if left undisturbed, they may completely resorb in 1–2 years. Therefore, secondary intervention procedures are of uncertain timing and should sometimes be delayed. Treatment in these settings generally comprises open flap grafting procedures instead of repeating the distraction procedure, which may not be advisable when flap blood supply has been significantly disturbed.

Adjacent teeth compromise

A second important consideration in segment transport is the status of the bone support of the adjacent teeth. Vertical distraction will generally not exceed the bone level present on adjacent tooth roots. For this reason adjacent teeth must be force-erupted orthodontically, or

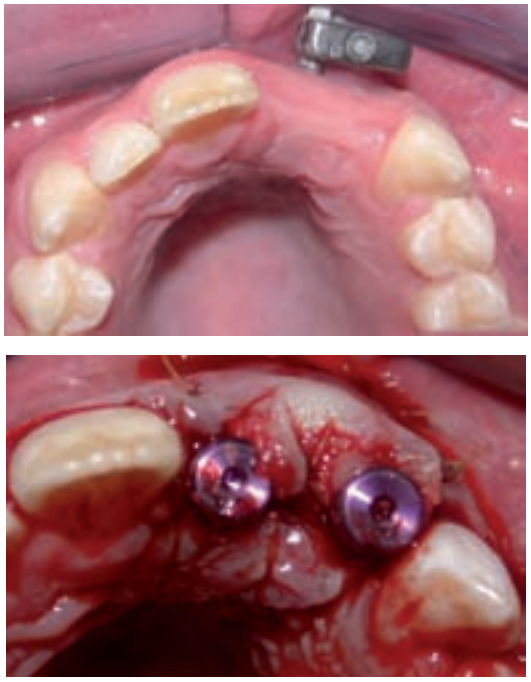
be included in the distraction if the esthetic demand requires a bone level beyond that available on the adjacent teeth. On occasion, adjacent teeth with significant bone loss are sacrificed to allow for greater vertical distraction. When this issue is ignored, such as in the anterior maxilla, esthetic compromise will likely result.

Device failure

Other misadventures with alveolar distraction include device failure or device misapplication with inattention to distraction vector. Most devices are unidirectional and therefore the lingual–palatal deflection of the transport segment must be taken to take into account. Much effort has been made to manage the lingualized distraction segment. Placement of the device with a compensating vector is one way to avoid this problem. Placement of a tooth-borne counter-traction device to help maintain the desired vector is another. If the deflection still occurs, one way to treat this is by the alveolar split-graft done 4–6 months later, which brings the buccal plate (osteoperiosteal flap) back into orthoalveolar form in most cases (Figs 15.9, 15.10).

Bidirectional devices or prosthetic or orthodontic techniques to move a malpositioned transport segment while the regenerate is still unmineralized have been attempted, but these approaches seldom completely bring the alveolar crest into axial alignment.

Infection is not a common finding with distraction unless the hardware loses fixation. If fixation is lost usually the hardware must be entirely removed, unless it can be refixated. This may lead to failure of the procedure or even loss of the transport segment that must then be salvaged by standard guided bone regeneration (GBR), block grafting or BMP-2 procedures.



Figs 15.9–15.10 If palatal deflection develops after vertical distraction, an alveolar split graft can in most cases bring the plate back into orthoalveolar form.

Secondary procedures

The most common complication observed with alveolar vertical distraction is the need for bone grafting and/or soft-tissue grafting following distraction. This is sometimes viewed as a complicating factor especially if clinician's or patient's expectations exceed the capability of alveolar distraction. Most postdistraction sites will require bone or soft-tissue grafting to establish the desired alveolar or gingival form in conjunction with implant placement. In one study, 20 consecutive distractions were followed prospectively and more than half of the cases required additional grafting procedures (2).

Sandwich osteotomy

The procedure with the most long-term use for edentulous vertical augmentation is the interpositional bone graft or sandwich osteotomy (Figs 15.11–15.13). This procedure, first used in the mandible in the 1970s and 1980s, was performed to improve denture retention. Only recently, however, was this procedure advocated for dental implant therapy (3–5).

The sandwich graft provides a fixed amount of vertical enhancement to a deficient alveolar ridge. Though up to 10 mm of vertical gain can be achieved, it is best to consider the sandwich graft for a 4–6 mm vertical augmentation most commonly prescribed for two to four tooth segments in the anterior arches.

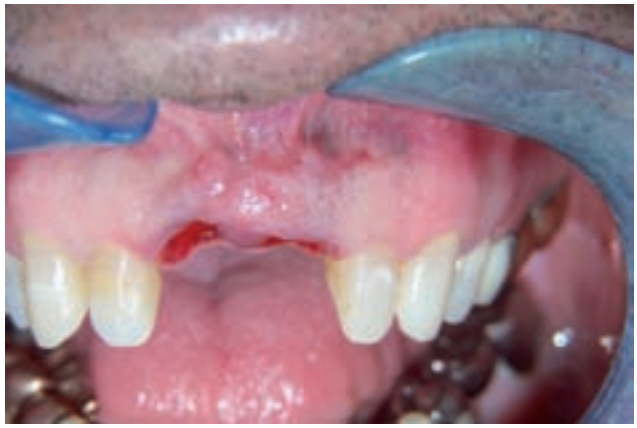
The sandwich graft is carried out through a vestibular incision above a horizontal osteotomy at the level of the vestibule and connected vertical osteotomy to the crest. The segment is moved crestally and bone grafted. Interpositional grafting follows (Figs 15.8, 15.9).

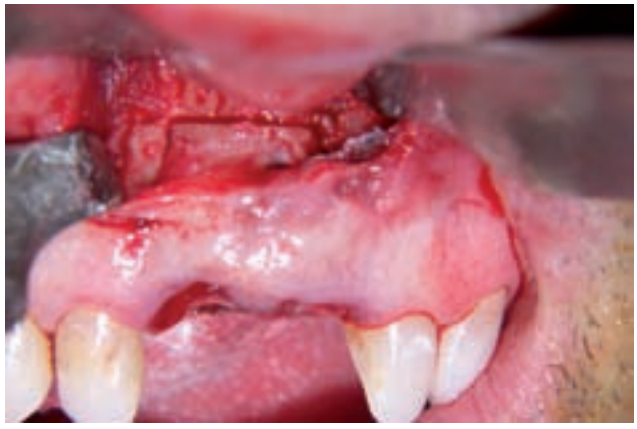
Complication: nasal floor fracture, elevated segment collapse

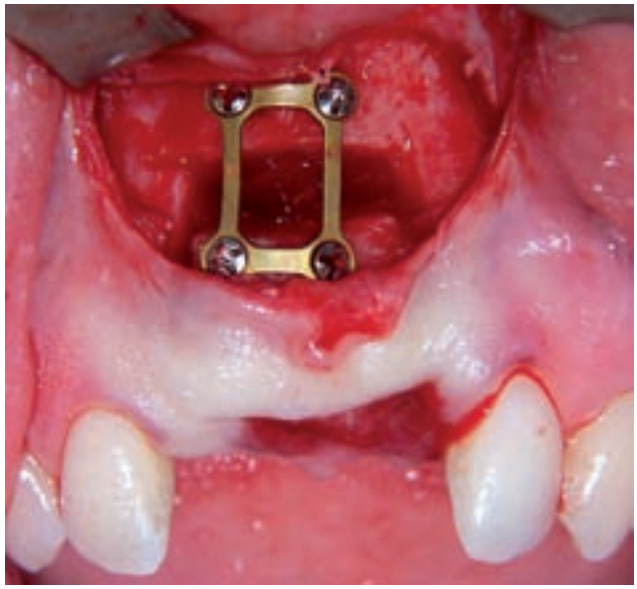
Etiology

The most common location for use of the sandwich osteotomy is the vertically deficient anterior maxilla. The horizontal cut must be made leaving a sufficient caudal segment, 5 mm or more in height, but also sufficient basal bone mass beneath the nose, i.e. a minimum of 3 mm. When the caudal segment is too small it may fragment or resorb after treatment and if the basal bone left beneath the nose is too thin it can in-fracture, preventing vertical movement of the segment. A perforation through the nasal mucosa may lead to infection developing in the interpositional graft site. In addition, when there is too

little bone to perform an osteotomy, fixation of the fragments is nearly impossible and the use of block inlay is ineffective. The cause of elevated segment collapse is multifactorial, including technical (early) and biologic (late).







Figs 15.11–15.13 Anterior maxillary atrophy is treated with a vestibular incision and a segmental osteotomy which is bone-plated into position.

Prevention

Orthognathic surgery complications are operator sensitive and therefore preventable by careful technique. The loss of a fragment of edentulous bone in an already deficient area is almost impossible to reconstruct except by iliac or BMP-2 grafting, each of which is of uncertain long-term stability. So the best way to avoid misadventure is prevention. Familiarity with orthognathic surgery protects the practitioner from making poor judgments and mistakes. As a general rule, orthognathic surgeons do not like to perform single- or even two-tooth osteotomies of a dentate alveolus as the blood supply is fragile and easy inadvertently to strip away, thus losing vitality. Small edentulous fragments carry the same risk.

Treatment

Vascular compromise

When a segment of bone has been lost or partially lost or the interpositional graft site has collapsed the site must be left for a number of months before iliac graft or BMP-2 reconstruction can be attempted. Vascular necrosis leaves highly scarred bone behind, requiring scar tissue to be removed and dead bone débrided away to basal bleeding bone before reconstruction can commence.

Palatal deflection

Like vertical alveolar distraction, palatal deflection occurs with this technique, especially if a greater than 5 mm vertical movement is attempted. For this purpose a secondary strategy is needed to reorient the alveolar crest into axial position should the elevated osteotomy be found to be in malposition. Though this can be left to heal and treated later with a book flap and simultaneous implant placement, as discussed previously for vertical alveolar distraction, the sandwich graft technique can instead be predictably mobilized buccally after rigid fixation is placed and at the time of surgery (Fig. 15.14).

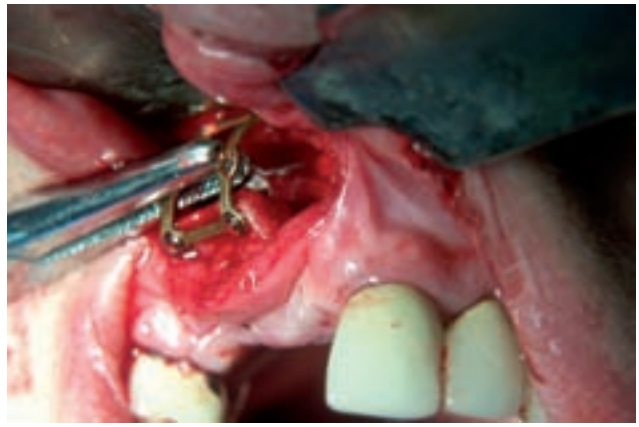


Fig. 15.14 Malpositioned segmental osteotomes can be repositioned into axial alignment by torquing the fixated titanium plate.

After alveolar elevation and bone plate placement with the alveolus secure at the desired alveolar plane, the bone plates are bent and torqued forward, which mechanically moves the segment facially into axial alignment. The complication of a palatally positioned crest is corrected in this way.

If the segment is adequate in size and vitality but has already healed, though displaced palatally, which is a common complication with the technique, an alveolar split can bring the facial plate back into alignment in a second grafting procedure done 4 months after the sandwich osteotomy.

Other than segment malposition, complications that occur with the sandwich technique are damage to vital adjacent structures (nerve, teeth, or implants), improperly sized segments (too small or too large a segment) and disruption of the soft tissue leading to vascular compromise. Plate exposure and infection can occur as well, but if a block inlay graft is used interpositionally fixation can be avoided.

Surgical treatment tips

A broadly based alveolus that is vertically deficient only is very dependably treated with the sandwich osteotomy technique. Unfortunately this is seldom found in the anterior maxilla, where it is most desirable to use the technique. In addition, the bigger the caudal fragment, the greater the likelihood of alveolar stability.

Alveolar width distraction

Alveolar width distraction is an ingenious procedure that splits the alveolus and slowly widens the developing interposed callus, making high-quality bone that is much more likely to osseointegrate subsequently placed dental implants than alveolar split-graft sites (Figs 15.15–15.17). The complication that commonly occurs in inexperienced hands with width distraction is complete loss of the facial plate owing to vascular compromise.

Alveolar width distraction is done through a minimally reflected crestal incision: a blind alveolar split is made using Piezosurgery® with vertical osteotomy to limit the split anteriorly and posteriorly. The split is usually 10 mm in height. An osteotome is inserted to widen the site slightly and the distractor is placed. After a latency period 0.5 mm/day distraction is done for 4–8 days to create a site wide enough for an implant. Six weeks later the distractor is removed and implants are placed.

Complication: devitalized buccal plate

A moderate alveolar width deficiency of 3 or 4 mm in the presence of sufficient alveolar height can be split from the alveolar crest, creating a buccal osteoperiosteal flap that may be distracted 4–6 mm laterally to gain alveolar width. Complications from this procedure are due to the alveolar split segment, which can fragment, be detached from the flap, or be inadequately mobilized by the osteotomy so that distraction cannot proceed. The most common technical problem is inadequate osteotomized bone mass due to too lateral placement of the osteotome or piezoknife. When perforated, fragmented, or detached from the flap, a small segment of bone may entirely resorb or be sequestered. One uncommon complication is lingual fracture and lingual displacement of the distraction segment (6) (Fig. 15.18).

Etiology

The complication of a devitalized facial alveolar plate is most often caused by poor surgical technique including too vigorous flap reflection stripping away blood supply, inadequate alveolar split leaving a small fragment that cannot be expanded, or poor placement of the distraction device leading to instability. All of these are technical issues in the category of poor wound management, and can all lead to vascular compromise.

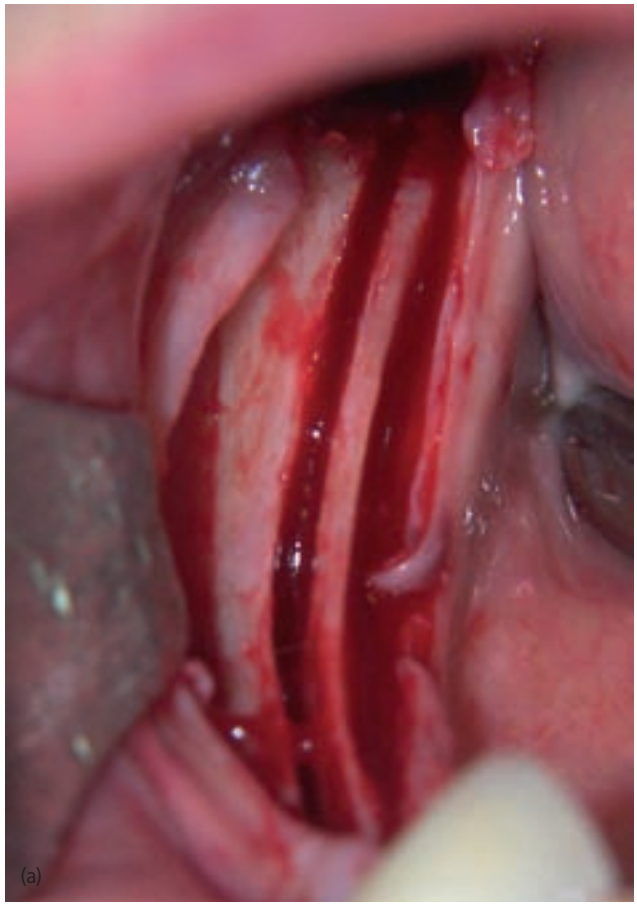
Prevention

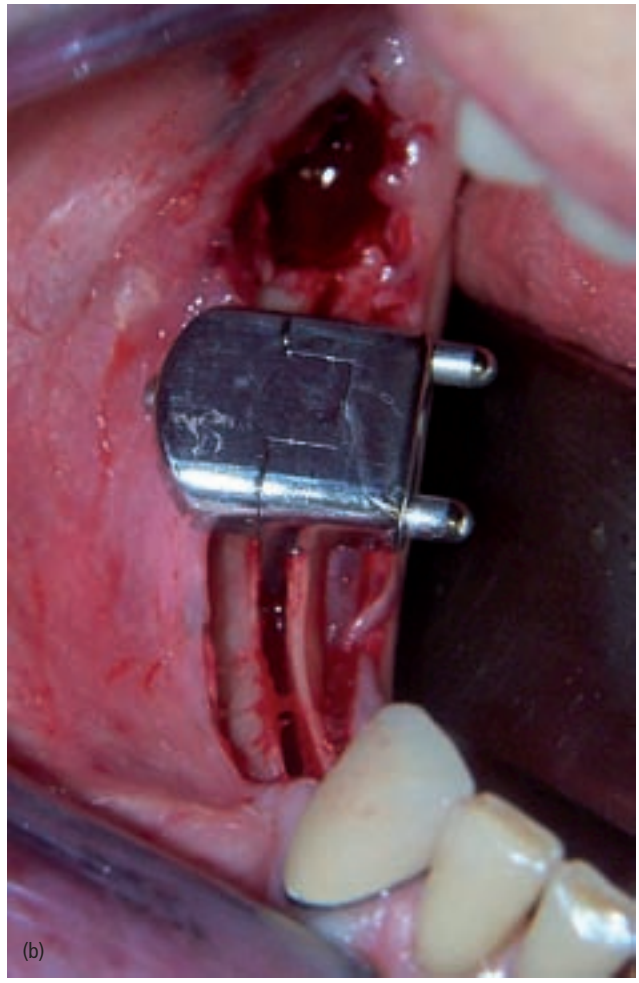
One way to prevent a too vigorous mucoperiosteal reflection is to take a nearly blind approach with minimal crestal mucoperiosteal reflection, using a finger to support the facial soft tissue during the osteotomy procedures. Support for the segment is important during device seating, which is achieved with a mallet during stabilization of the device. When a distraction device becomes loose at any stage this generally leads to failure of treatment, so distraction cases must be monitored throughout treatment.

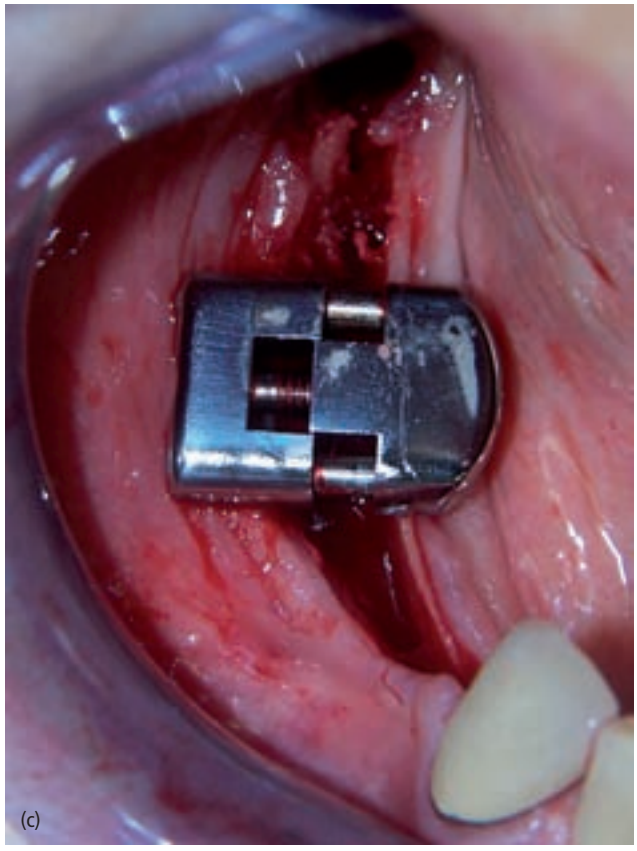
Treatment

Technical problems

Once the alveolus has been split and the device placed, a mock distraction is done for a few millimeters of widening to ensure mobility of the facial segment. The segment should move evenly. One complicating factor that occurs is only partial corticotomy on one side or the other so that the fragment does not move at one side. When this happens the device should be removed and the vertical osteotomy completed on the non-mobile side. When widening requires too much force and the fragments do not move apart or the facial plate suddenly fractures, a back-cut at the base of the facial plate is needed. Experienced surgeons can do this without flap reflection using a tunneling approach high in the vestibule. If a full flap reflection occurs, the vestibular horizontal osteotomy can be completed and the wound closed for 3 weeks.







Figs 15.15–15.17 Width distraction proceeds after alveolus splitting using a 0.5 mm/day protocol.

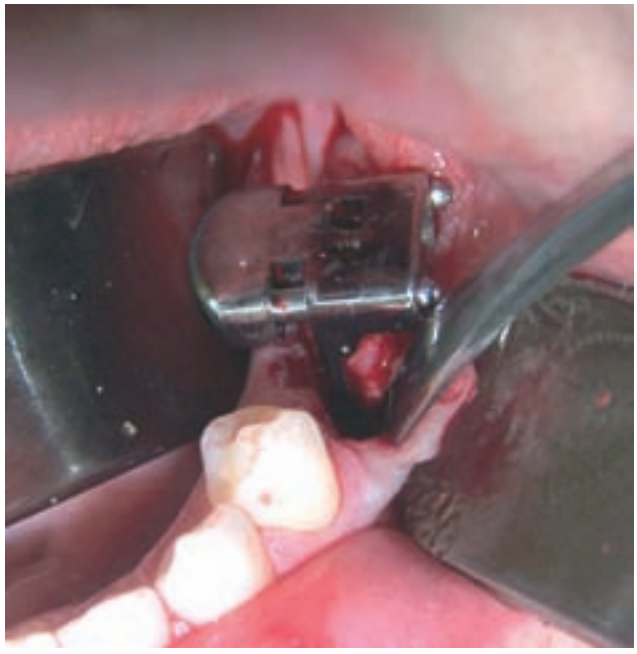


Fig. 15.18 The lingual plate fractured upon implant placement which occurred 6 weeks after the initial alveolar split surgery.

After that period the distraction device can be replaced and treatment may proceed.

Lingual fracture
One uncommon complication is lingual fracture and lingual displacement of the distraction segment that may require aborting the procedure. Lingual plate vascular embarrassment should not occur so healing should proceed, but the distraction procedure should most likely be terminated.

Vascular compromise
Once loss of the buccal plate has occurred, reconstruction of an extremely narrow alveolus suggests a latent augmentation strategy with an open-flap approach. Usually soft tissue has also been lost such that recovery of pristine alveolar–gingival tissues becomes impossible.

Book flap
The alveolar split osteoperiosteal flap or book flap is used to widen the narrow alveolus with interpositional bone graft or simultaneous implant placement (7) (Figs 15.19–15.21). Implants placed at the time of alveolar split commonly develop gingival recession. This is due to vascular compromise of the marginal aspect of the buccal bone segment.

The book-flap technique is an alveolar split similar to that described for width distraction, but widened immediately and interpositionally grafted. A crestal incision is made and blind osteotomies conducted to a depth of 10 mm, splitting the alveolar process. Implants are placed 4 months later.

Complication: gingival recession

Etiology

All of the technical complications for alveolar split grafting are based on poor surgical technique. The treatment plan may be appropriate, but execution of the plan flawed. The use of Piezosurgery®, minimal flap reflection and a modest widening strategy help protect the surgeon from misuse of the technique. When late facial plate resorption, manifest as gingival recession, occurs at the marginal bone of a restored implant this can most always be traced to inadequate alveolar split wound management. A non-biologic trespass has occurred leading to marginal bone necrosis. A poorly executed alveolar split that later led to gingival recession is seen in Figs 15.22 and 15.23.

Prevention

Prevention of avascular necrosis, sequestration, infection, non-union, or collapse of the expansion, all of which are manifest as late-term marginal bone resorption, can be prevented by adhering to strict biologic principles:

- Do not traumatize bone.
- Do not strip the blood supply from bone.
- Manage the wound biologically.

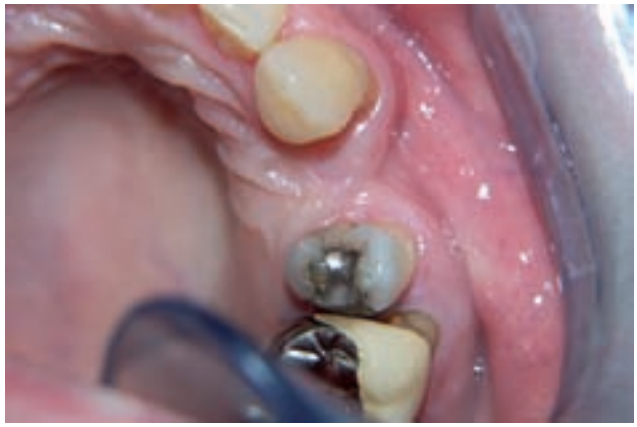
The fulfillment of all of these principles is to perform the split osteotomy by creating a substantially thick, minimum 2 mm, facial plate that remains vitally attached to either partial-thickness or full-thickness flaps. In other words, maintain an osteoperiosteal flap.

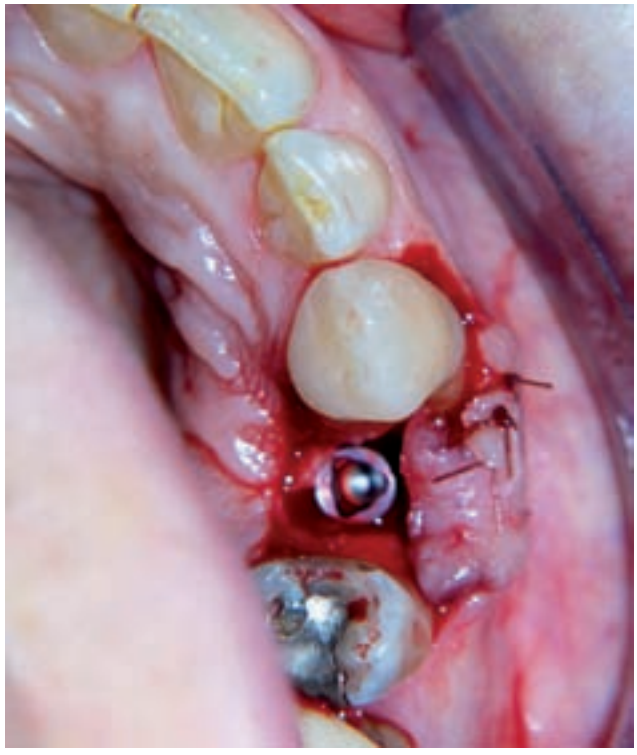
Infection and sequestration of the segment can be prevented by good wound closure, usually assisted by collagen filler at the crest when widening prevents primary closure. The wound should not be traumatized by a removable prosthesis. This may lead to non-union and scarification of the interpositional graft site, and may even dislodge the facial plate.

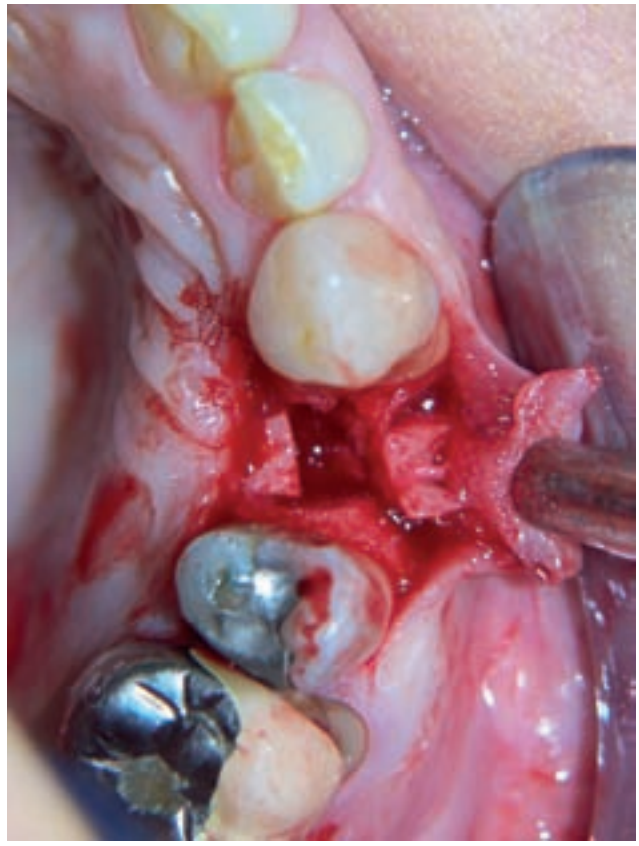
Treatment

Loss of buccal plate
When sequestration, dehiscence, or infection occurs there is no salvaging what is non-vital and contaminated. The entire graft and probably the facial bone fragment will need to be removed.

Loss of papillae
Loss of adjacent subpapillary bone is one of the most damaging consequences of failed alveolar split grafts. The site now becomes a vertical as well as horizontal defect which has extended the borders of the lesion. Treatment in this setting may now involve orthodontic forced eruption or even vertical distraction osteogenesis







Figs 15.19–15.21 The book flap is an alveolar split graft used to widen the alveolus, here shown with simultaneous implant placement.

with inclusion of adjacent teeth. In severe cases teeth may need to be removed. These complication settings are severe and often non-treatable, generally proceeding to finalization with non-implant restorations rather than undergoing extensive grafting or distraction options.

Other complicating factors of alveolar split are those common to any bone grafting procedures, including dehiscence, infection, nerve injury, and bone resorption. Of these, perhaps bone resorption is the most significant and is most often due to soft-tissue mishandling.

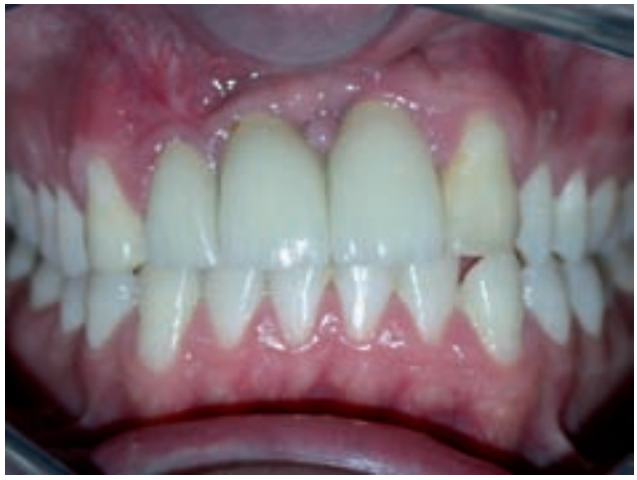
Surgical tips

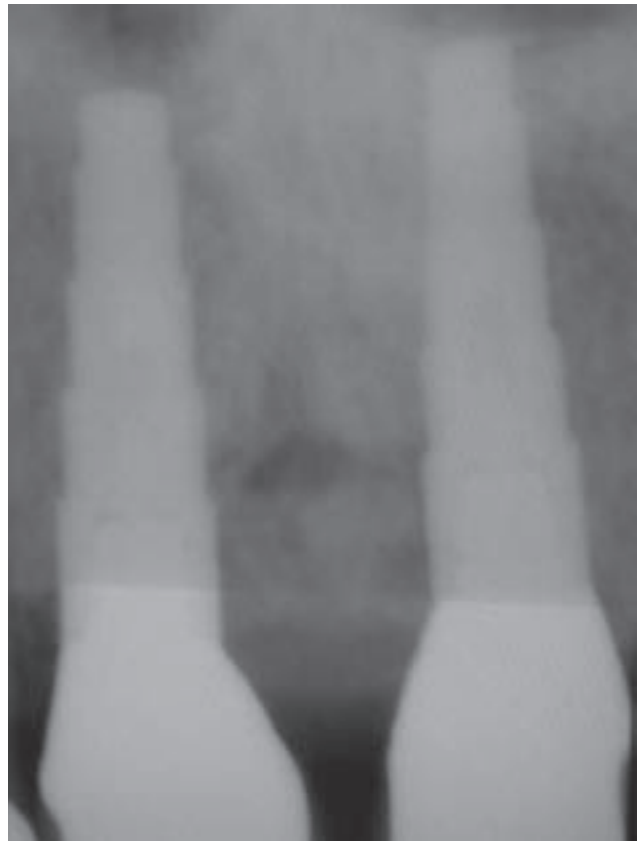
Divide a thick piece of bone, not a narrow one. A 2 mm wide ridge should be treated in another way. Use Piezosurgery® for the most part in performing alveolar split procedures.

Major orthognathic distraction procedures

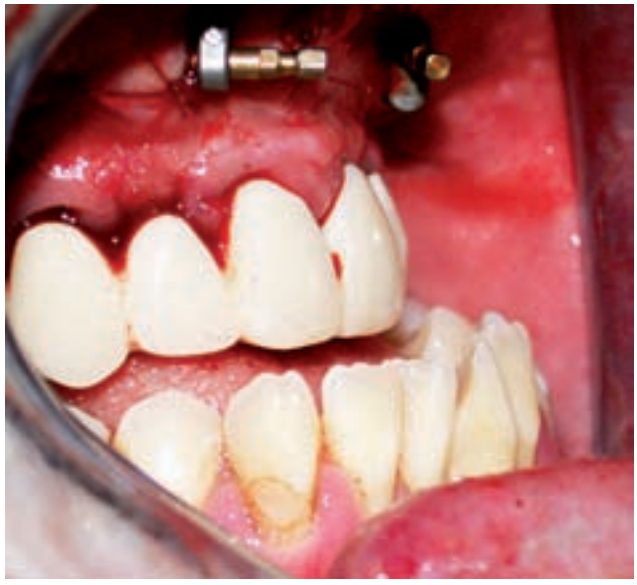
Complication: distraction failure or relapse

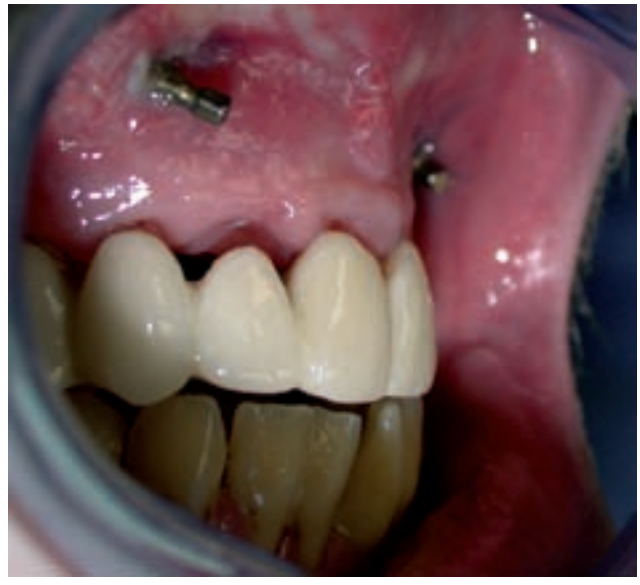
Major orthognathic or jaw distraction procedures including rapid palatal expansion, Le Fort I down graft, Le Fort I distraction, mandibular advancement distraction, or body distractions in either jaw are ways of establishing orthoalveolar form by first establishing orthoalveolar relation, that is, class I jaw relation. These procedures are highly advanced and infrequently performed at present, and are mentioned here only to complete the discussion on variations in which the alveolar process can be re-established in three-dimensional space. A discussion of complications for these procedures is beyond the scope of this chapter (8).





Figs 15.22–15.23 Alveolar split graft that led to facial plate resorption and long restorations.





Figs 15.24–15.25 A Le Fort distraction requires bilateral device placement and usually entails 10 mm or more maxillary advancements.

A Le Fort I distraction procedure involves a standard circumvestibular incision made high in the vestibule. The sinus membrane is elevated bilaterally through a Caldwell Luc approach. Horizontal osteotomies are extended to the nasal aperture and pterygomaxillary suture. The pterygomaxillary sutures are disarticulated and the nasal septum freed. The maxilla is down-fractured and mobilized. Sinus bone grafts are placed. A distraction device is placed bilaterally. Activation begins 1 week later at a rate of 1 mm/day until movement is complete (Figs 15.24, 15.25). A 4-month consolidation period follows.

Take-home hints

- Complication avoidance is the primary treatment protocol for managing bone grafting procedures.
- The team approach and development of a surgical and prosthetic treatment plan are vital to success. A team approach will most likely lead to the required expertise, i.e. good clinical judgment.
- Although technical failure will occur at times, as long as the biologic basis of a surgical procedure is maintained while adhering to the prosthodontic treatment plan, irreversible complications will be uncommon.
- The most important principle to adhere to is circumspect wound management both during and after surgery.
- One may think of complication management as technical or medical management, such as an incision and drainage procedure or managed antibiotic therapy, but well thought-out procedures, known to be achievable and well founded in the literature, lead to a very low incidence of complication – the best treatment strategy of all.

References

1. Jensen OT. In Reply: Robiony M, Costa F, Politi M. Letters to the Editor: Alveolar sandwich osteotomy of the anterior maxilla. *J Oral Maxillofac Surg* 2006; **64**: 1453–64.
2. Jensen OT, Cockrell R, Kuhlke L, Reed C. Anterior maxillary alveolar distraction osteogenesis: a prospective 5-year clinical study. *Int J Oral Maxillofac Implants* 2002; **17**: 52–68.
3. Jensen OT. Alveolar segmental "sandwich" osteotomies for posterior edentulous mandibular sites for dental implants. *Am Assoc Oral Macillofac Surg* 2006; **64**: 471–5.
4. Jensen OT, Kuhlke L, Bedard JF, White D. Alveolar segmental sandwich osteotomy for anterior maxillary vertical augmentation prior to implant placement. *J Oral Maxillofac Surg* 2006; **64**: 209–96.
5. Jensen OT, Cullum DR, Baer D. Marginal bone stability using 3 different flap approaches for alveolar split expansion for dental implants: a 1-year clinical study. *J Oral Maxillofac Surg* 2009; **67**: 1921–30.
6. Laster Z, Rachmiel A, Jensen OT. Alveolar width distraction osteogenesis for early implant placement. *J Oral Maxillofac Surg* 2005; **63**: 1724–30.
7. Jensen OT, Ellis E. The book flap: a technical note. *J Oral Maxillofac Surg* 2008; **66**: 1010–14.
8. Jensen OT, Branca R. Lefort I downgraft with sinus elevation. In: Jensen OT, ed. *The sinus bone graft*, 2nd edn. Chicago, IL: Quintessence, 2006: 241–50.

Chapter 16

Complications in lateral window sinus elevation surgery

Stephen S. Wallace DDS

Introduction

Sinus elevation surgery is today considered the most predictable of the preprosthetic site-development bone augmentation procedures (1). This high level of predictability has been shown in two ways. The first is that the outcome of lateral wall sinus elevation surgery, as measured by implant survival in evidence-based reviews, has been shown to be highly predictable (1–3). By making the appropriate evidence-based decisions regarding grafting materials, implant surfaces, and the use of barrier membranes over the lateral window, one can expect implant survival rates to be above 95%. The second is that complications are infrequent and those that occur during and after sinus grafting procedures are for the most part localized and readily remedied (4–7).

This chapter will discuss the major intraoperative and postoperative complications and present both recommendations for complication prevention and treatment options should complications occur.

Intraoperative complications

Intraoperative complications are primarily the result of surgical difficulties encountered during the course of the procedure. These may be the result of the presence of complex anatomic situations (thin membranes, septa, thick or convex lateral walls), the choice of less predictable treatment options, inadequate systemic or local diagnosis, or operator error.

The most common intraoperative complication is Schneiderian membrane perforation. Other complications include intraoperative bleeding, perforations in the buccal flap and, much less frequently, injury to the infraorbital nerve.

Intraoperative bleeding

Etiology and incidence

Intraoperative bleeding results from severing or damaging branches of the vascular supply to the lateral wall of the sinus and the surrounding soft tissues. This bleeding is usually minor and of relatively short duration, but in some instances it can be profuse and difficult to control in a timely manner. Solar *et al.* (8) described the blood supply to the lateral wall of the maxillary sinus in cadaver specimens. It consists of the intraosseous and extraosseous branches of the posterior superior alveolar artery which form an arterial cascade with the infraorbital artery. Bleeding may occur either from the soft tissue (extraosseous branch) during flap elevation or directly from the lateral bony wall (intraosseous branch) during preparation of the lateral window via rotary instrumentation. There is also the possibility of bleeding from the medial wall of the sinus if the posterior lateral nasal artery is damaged (9). The posterior superior alveolar, infraorbital, and posterior lateral nasal artery are all branches of the maxillary artery.

Prevention

Solar (8) showed the internal branch of the posterior superior alveolar artery to be present in 100% of cadaver specimens. Elian *et al.* (10) showed that this artery can be located in the lateral wall in cross-sectional computed tomographic (CT) images in 52% of sinuses. Further, in 20% of these cases, the artery is in a position in which it is likely to be cut when creating a lateral window. In a similar CT-scan study Mardinger *et al.* (11) located the artery in the lateral wall in 55% of sinuses. Although a bleeding incident does not occur on every occasion that this artery is damaged, it seems prudent to use three-dimensional (3D) planning as a means of avoiding, if possible, an encounter with the artery (Fig. 16.1). In some cases the artery can be visualized, within the lateral wall, after elevation of the flap (Fig. 16.2). In many instances a window can be made coronal to the location of the artery and the superior portion of the membrane elevation can be performed internally to the required apical height (Fig. 16.3). It should be realized however, that the artery is not always located within the lateral wall. The artery can be located just internal to the lateral wall and may pass in and out of the bony wall throughout its antero-

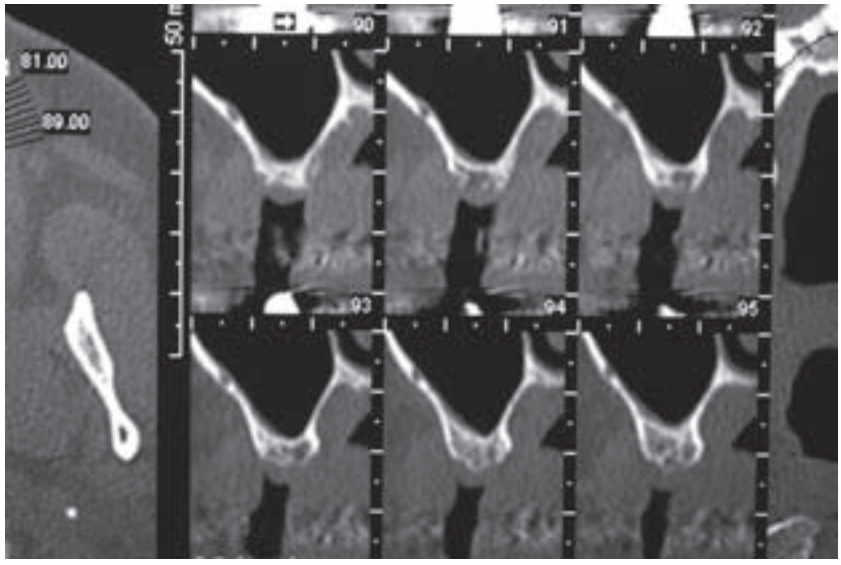


Fig. 16.1 Artery visualized in the lateral wall after flap reflection.

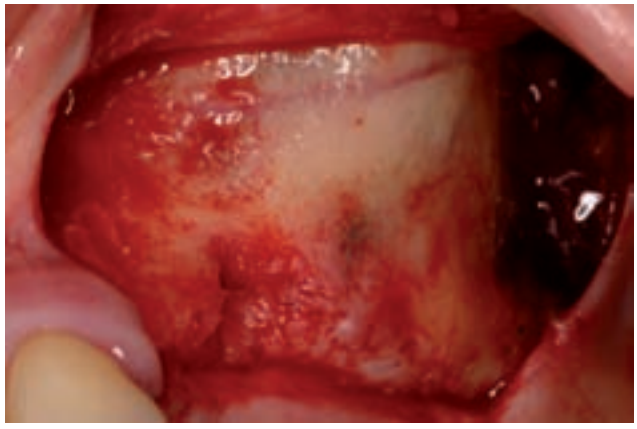


Fig. 16.2 Artery dissected from the lateral wall.

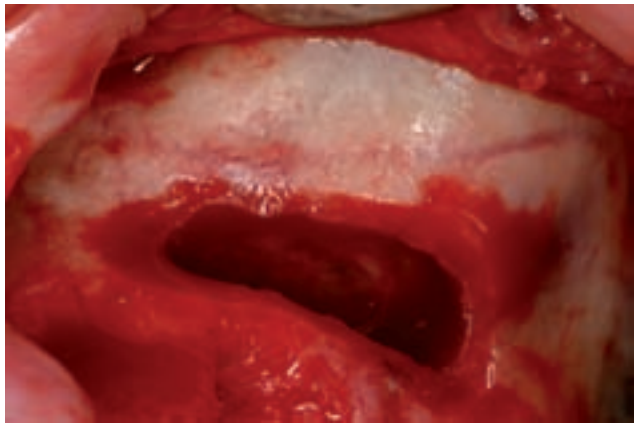


Fig. 16.3 Artery elevated with membrane.

posterior course. In this internal position, it is susceptible to damage from both rotary and hand instrumentation.

Once it is anticipated that the possibility of a bleeding complication exists, it is prudent to locate the position of the artery on the cross-sectional CT images and then use a window preparation method that can respect the integrity of vascular and other soft tissues while still creating the window in the ideal location for access to and elevation of the sinus membrane. If rotary instrumentation is used, diamond burs are preferable to carbide burs as they are less likely to catch and tear the membrane. Piezosurgery®, a concept of bone surgery developed by Vercellotti and specifically adapted for sinus elevation surgery (12), provides a means of avoiding this complication almost entirely. Piezoelectric surgery uses low-frequency ultrasonic vibrations (range of 24–32 kHz for the various systems) to perform cutting (osteotomy) and grinding (osteoplasty) procedures on bone. This low-frequency, selective cutting action provides safety for soft tissues as it is incapable of cutting either blood vessels or the Schneiderian membrane. Piezoelectric surgery has been used successfully to avoid soft-tissue complications (both vascular and neural) in numerous oral surgical procedures such as Le Fort osteotomies (13) and mandibular sagittal split osteotomies (14). Piezosurgery® has seen widespread use in Europe for over 10 years and today at least six piezoelectric surgery devices are available in the US market. Since introduction of this technique to the USA in 2005, numerous clinicians have realized its advantages in sinus elevation surgery. Piezoelectric surgery has minimized, and in many cases prevented, bleeding episodes during preparation of the lateral window. The selective cutting action (bone cutting only) allows the operator to dissect the posterior superior alveolar artery from the bony window area, leaving it completely intact (Figs 16.4, 16.5).

Treatment

Many techniques exist to control vascular bleeding in sinus elevation surgery. These include:

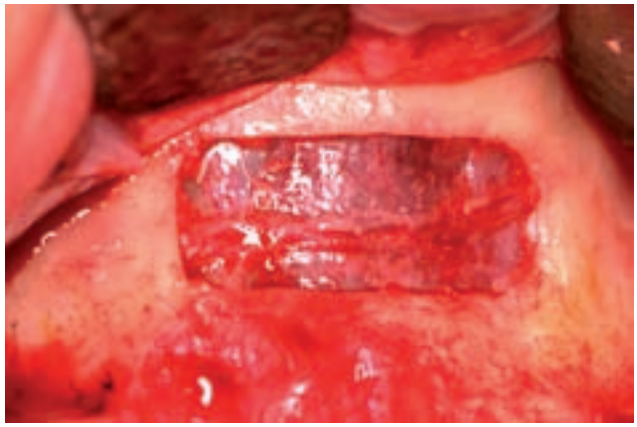


Fig. 16.4 Artery dissected from the lateral wall with piezoelectric surgery.

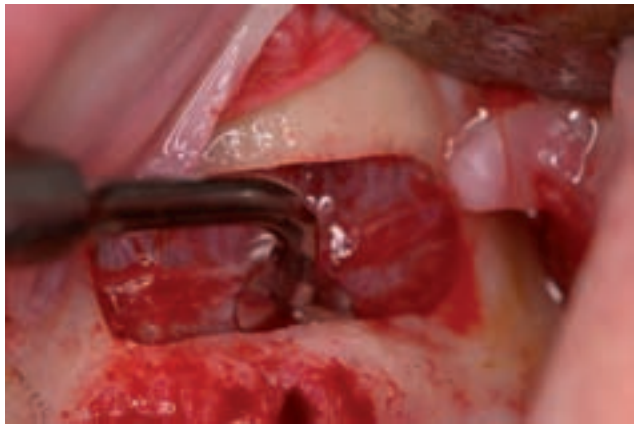


Fig. 16.5 Elevation of membrane with intact artery.

- direct pressure on the bleeding point
- use of a localized vasoconstrictor
- bone wax
- crushing the bone channel around the vessel
- use of electrocautery (with care near membranes)
- suturing of the vessel proximal to the bleeding point.

The use of a vasoconstrictor (1:50 000 epinephrine) and electrocautery are more effective in controlling the soft-tissue bleeding that may occur when making releasing incisions before elevation of the mucoperiosteal flap. Electrocautery, when used to control vascular bleeding from bone in the vicinity of the Schneiderian membrane, may result in membrane damage and therefore should be used with caution. Crushing the bleeding end of an intrabony vascular channel to compress the bone and vessel may be effective but care again must be taken to avoid membrane perforation by direct pressure.

Bleeding encountered during sinus elevation will usually be gently flowing in nature. In some instances, however, this bleeding may be pulsating. In general, the appearance is worse than the severity of the condition. Bleeding, even of the pulsating variety, will stop spontaneously or after several minutes of direct pressure as a result of clot formation within the bone channel surrounding the artery. One technique that may be used is to have the surgical assistant place a high-volume, narrow-tipped evacuator close to the bleeding point to eliminate directly the blood flow into the surgical field. Window preparation, membrane elevation, and grafting can be completed while controlling bleeding in this manner. The bleeding usually stops by the time the grafting is completed and, after closure, postoperative bleeding is not encountered.

Take-home hints

- Obtain preoperative CT images to locate the vessel.
- Visualize the vessel clinically.
- Avoid the vessel when designing the window.
- Use piezoelectric surgery to avoid trauma to the vessel.
- Have materials on hand to control bleeding (electrocautery, local with 1:50 000 epinephrine, bone wax).

Schneiderian membrane perforation

Etiology and incidence

Perforation of the Schneiderian membrane is the most common intraoperative complication in sinus elevation surgery (15, 21). The reported incidence in the literature varies from lows of 11% (7) and 14% (16) to a high of 56% (17) when rotary window preparation is used. Most experienced clinicians estimate their perforation rate to be approximately 25%. In retrospective CT-scan studies performed at the New York University Department of Periodontology and Implant Dentistry (Poster Presentations, AO Annual Meeting, 2002) the perforation rate was shown to be related to membrane thickness and to a lesser degree to the presence of septa. The perforation rate was 41% when the membrane thickness was less than 1.5 mm and 16.6% when thickness was greater to or equal to 1.5 mm. The perforation rate in a separate study of 136 sinus elevations was 44.2% when a septum was present and 35.7% when septa were absent. In a CT study by Cho *et al.* (18), the perforation rate was shown to be related to sinus width or, to be more specific, the angle made by the medial and lateral walls at the crest of the alveolus. The perforation rates were 62.5% for the narrow anterior part of the sinus (angle < 30°), 28.6% for the wider middle part of the sinus (angle 30–60°), and 0% for the widest posterior portion (angle > 60°).

There are numerous maneuvers that must be performed during sinus elevation surgery that place the Schneiderian membrane at risk. These include:

- flap elevation (placing an elevator through a thin crest or lateral wall or through a previous oroantral fistula that has healed with soft tissue only)
- preparation of the lateral window (specifically with rotary instrumentation)
- elevation of the Schneiderian membrane with hand instrumentation (especially medially and in close proximity to septa)
- placement of graft material (excessive pressure against membrane).

Prevention

A thorough knowledge of the 3D anatomy of the sinus is essential if the perforation rate is to be kept to a minimum. A CT analysis will give information relating to the thickness of the crest and lateral walls, presence of discontinuities in the bony walls, width of the sinus, slope of the anterior sinus wall, membrane thickness, and the presence, size, and location of septa. Clinicians will also gain information relative to sinus health and patency of the osteomeatal complex. This evaluation may indicate the need for presurgical treatment that can avoid complications such as postoperative sinusitis and infection. Figure 16.6(a, b) shows a defect in the lateral sinus wall created during a failed sinus elevation. Likewise, lateral wall defects may be created during extraction of teeth. It is possible that aggressive flap elevation could cause a tear in the membrane at this location. If a discontinuity is known to exist, a split-thickness flap dissection over the site will avoid a laceration of the sinus membrane. Having 3D knowledge of the existence, location, and anatomy of a septum will help determine the best location for the window to facilitate uneventful membrane elevation. A septum may initially be seen as a ridge crossing the sinus floor but it will generally continue as a spine, reaching its highest extent on the medial wall (Figs 16.7–16.9) (19). Septa can on occasion be quite large (Fig. 16.10) but, with proper access, they can be circumvented.

Once inside the sinus, good access and good vision will greatly facilitate membrane elevation. The location of the lateral window and its size will affect the clinician's ability to elevate the membrane safely. Having the window in a location that gives the best access to areas where instrument angulation, and hence membrane elevation, is difficult will have a profound effect on the operator's ability to keep his or her hand instruments directly on the bone surface. Changes in instrument angulation are required to go across the floor and up the anterior and medial walls. The anterior portion of the sinus can be very narrow, requiring coordination and vision to prevent inadvertent membrane perforation. Many experienced clinicians feel that the ideal location for the window is 3 mm superior to the sinus floor and 3 mm distal to the sloping anterior wall (Fig. 16.11a–c), which allows a controlled membrane elevation to be accomplished while keeping the elevating instruments on the bone surface at all times. Of the 11 perforations encountered by Zijderveld *et al.* (7), five were in relation to septa and four were made when releasing the membrane mesially with poor visibility. The superior extent of a sloping anterior wall may put it far from a traditional oval or rectangular window. The shape of the window in

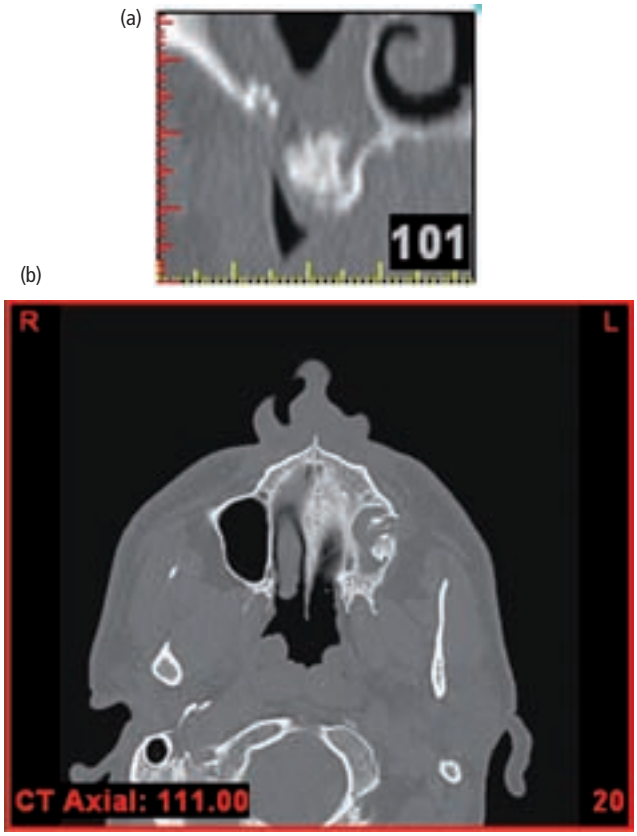


Fig. 16.6 (a) Cross-sectional CT-scan view showing defect in lateral wall. (b) Axial CT-scan view showing defect in lateral wall (left).

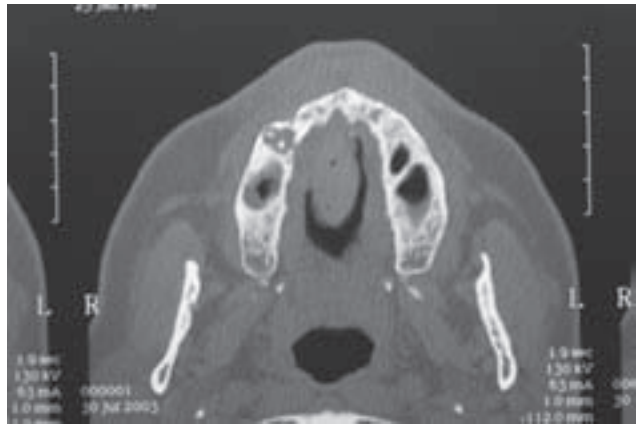


Fig. 16.7 Axial DentaScan view of a septum close to the sinus floor (left).

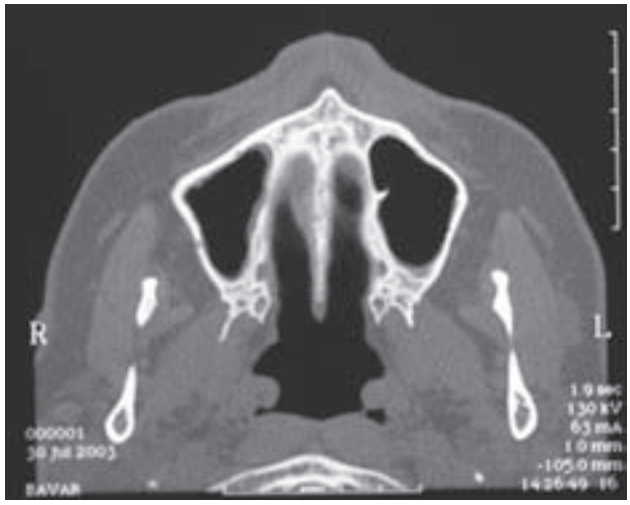


Fig. 16.8 Axial DentaScan view of the same septum as in Fig. 16.7 in more coronal location. Note spine on left medial wall.

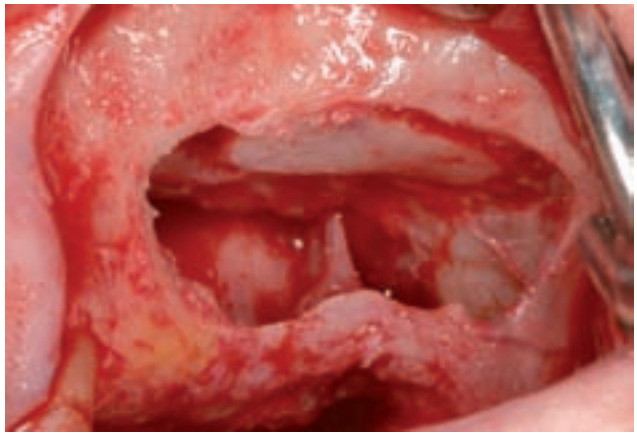


Fig. 16.9 Clinical view of the septum shown in Figs 16.7 and 16.8.

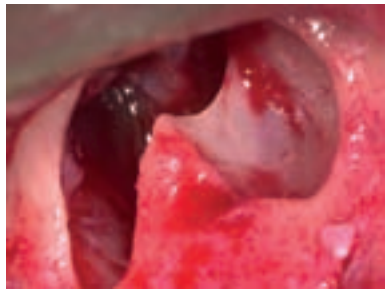


Fig. 16.10 Exceptionally large septum.

this type of case should be trapezoidal with the superior osteotomy being longer and more anterior than the inferior osteotomy, always keeping the window within 3 mm of the anterior wall. Remember that the anterior wall is an extension of the sinus floor and the most predictable way to reach it is by following the floor in an anterior and superior direction.

When septa are known to be present, it is advisable to lengthen the window in the anteroposterior direction so that the window is located both anterior and posterior to the septum. This allows for a lateral to medial elevation of the membrane from both sides of the septum. It must be realized that it is extremely difficult to elevate a membrane from a sharp septum in a mesial to distal direction while keeping the elevator on the bony surface at all times. While making two separate windows has been proposed for this task (7, 20), some explanation is required. It is likely that the two separate windows will be so decreased in size that access and vision will be made even more difficult. In practice, the two windows are joined at the septum, creating one large window with improved access to both sides of the septum. A useful piezoelectric surgery technique is to perform a full osteoplasty of the lateral window. This will readily reveal the location of a septum and allow for its removal and subsequent membrane elevation from both sides (Figs 16.12a, b; 16.13a, b).

Piezoelectric surgery again proves itself to be a valuable adjunct in sinus surgery in that its use has been shown by most authors and clinicians to result in decreased membrane perforation rates. This is due to the fact that piezoelectric inserts do not cut soft tissue. In a series of 100 consecutive sinus elevations using piezoelectric surgery, Wallace *et al.* (21) reported a membrane perforation rate of 7%. In this series all perforations occurred when completing the elevation via hand instrumentation, with no perforations occurring when using the piezoelectric inserts. Blus *et al.* (22) reported two perforations in 53 sinus elevations for a 3.8% perforation rate using two different piezoelectric devices. In a report of 56 consecutive sinus elevations, Toscano *et al.* (23) reported a 3.6% perforation rate using piezoelective surgery. Conflicting data were reported by Barone *et al.* (24), who reported on 13 bilateral cases using Piezosurgery® on one side and a rotary diamond window preparation on the other as a within-patient control. The perforation rate was 30% with Piezosurgery® compared to 23% with the diamond bur control. Barone's results are contrary to other publications and the positive experience with piezoelectric sinus elevation surgery at the New York University Department of Periodontology and Implant Dentistry for the past 5 years.

Piezoelectric and conventional rotary surgical techniques should differ depending on the thickness and shape of the lateral sinus wall. If the window is thin, a diamond insert can be used to make a superior hinge or a free-floating bone island attached to the membrane (Fig. 16.14a, b). This is then elevated horizontally. If the lateral wall is thick or it becomes convex in the malar eminence area, the entire lateral wall in the window area can be eliminated via osteoplasty (Fig. 16.15a–f). You will be looking directly at the Schneiderian membrane which

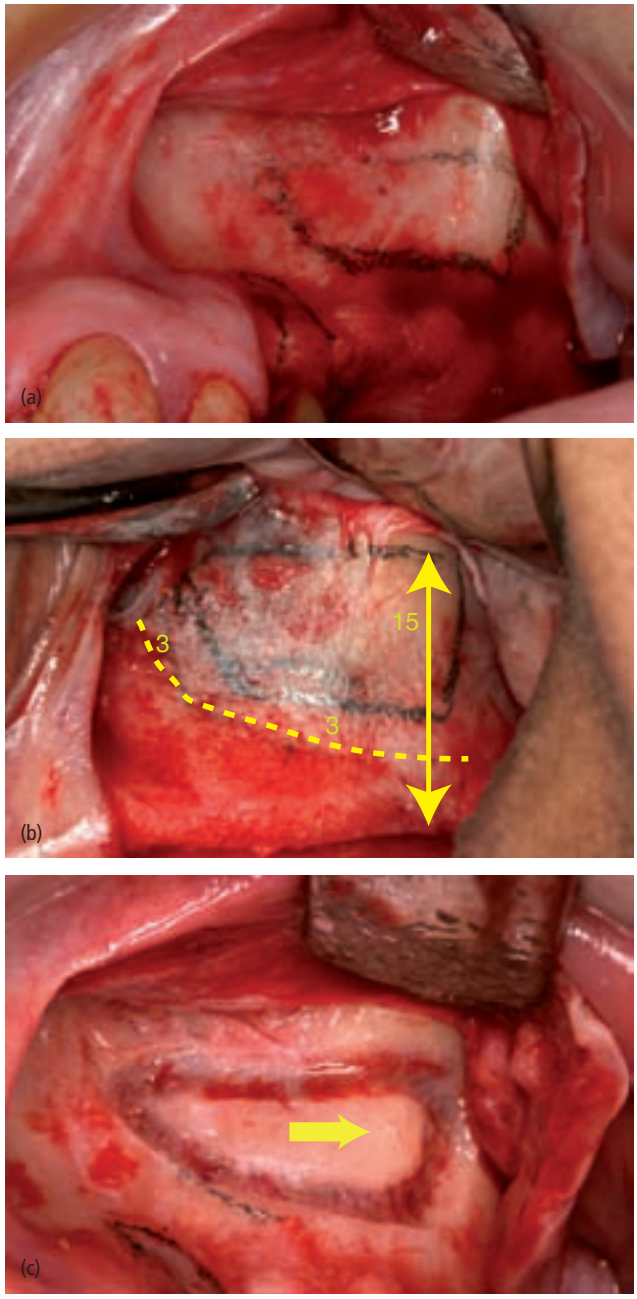


Fig. 16.11 (a) Sinus with a sloping anterior wall and thickness in the malar area. (b) Ideal location of a window for uneventful membrane elevation. (c) Trapezoidal window 3 mm from the floor and anterior wall. Note that the wall thickness was reduced in the malar area (arrow) for better visibility of the membrane and to facilitate the hinging process.

can now be elevated with a combination of piezoelectric and manual elevators. Working directly against the membrane may seem to place the membrane at risk for perforation, but the membrane may be even more susceptible to damage from the sharp edges of an elevated bony window. While a histologic comparison of vital bone formation with these two techniques is lacking at this time, clinical evidence from the author's 5-year experience with this technique does not show a difference in outcome as measured by implant survival.

Treatment

An intact sinus membrane is essential for graft containment when using a particulate autogenous or particulate bone replacement graft as a sinus grafting material. This is not necessarily the case when using block grafts (25, 26). Elevation of the membrane helps to form a compartment in which the particulate graft material is placed and confined. The elevated membrane forms the distal and superior walls of this compartment, while the bony sinus walls form the inferior (crest), anterior, medial and lateral walls. Proussaefs *et al.* (27) showed that failure to contain the particulate graft due to membrane perforation will result in decreased bone formation (14.2% vs 33.6%) and a decreased implant survival rate (70% vs 100%).

Should the sinus membrane be torn or perforated, the fragility of the remaining membrane is increased and care and delicacy is required to complete the elevation. This is best accomplished by elevating the membrane around the perforation, thereby releasing tension on the perforated area of the membrane, as opposed to working directly in the weakened area of the perforation. It is still necessary to complete the sinus membrane elevation from the floor, medial, and anterior bony walls to allow the blood supply from the bony walls to vascularize the graft. Some clinicians opt to make a small repair to stabilize the damaged area before completing the elevation. If this is done the repair should be evaluated for stability before placing the graft material.

The most common means of repairing a perforated Schneiderian membrane is to use a bioabsorbable collagen barrier membrane as a patch. Other techniques involve the use of sutures (difficult), platelet-poor plasma (PPP) spray or plasma rich in growth factors (PRGF) applications (if available at the time of perforation), and the use of lamellar bone sheets.

Many techniques have been reported using bioabsorbable collagen barrier membranes for repairs. These techniques are specifically chosen based on both the size and location of the perforation and the perceived need to stabilize the repair to keep it securely in place. Without stabilization it is possible for the repair membrane to shift in position or even be drawn up through the perforation into the body of the sinus during or after graft material placement. The choice of a specific repair membrane will be based on the above factors as well as the physical characteristics of the membranes available for use in perforation repairs. The following generalizations should be helpful when attempting repairs:

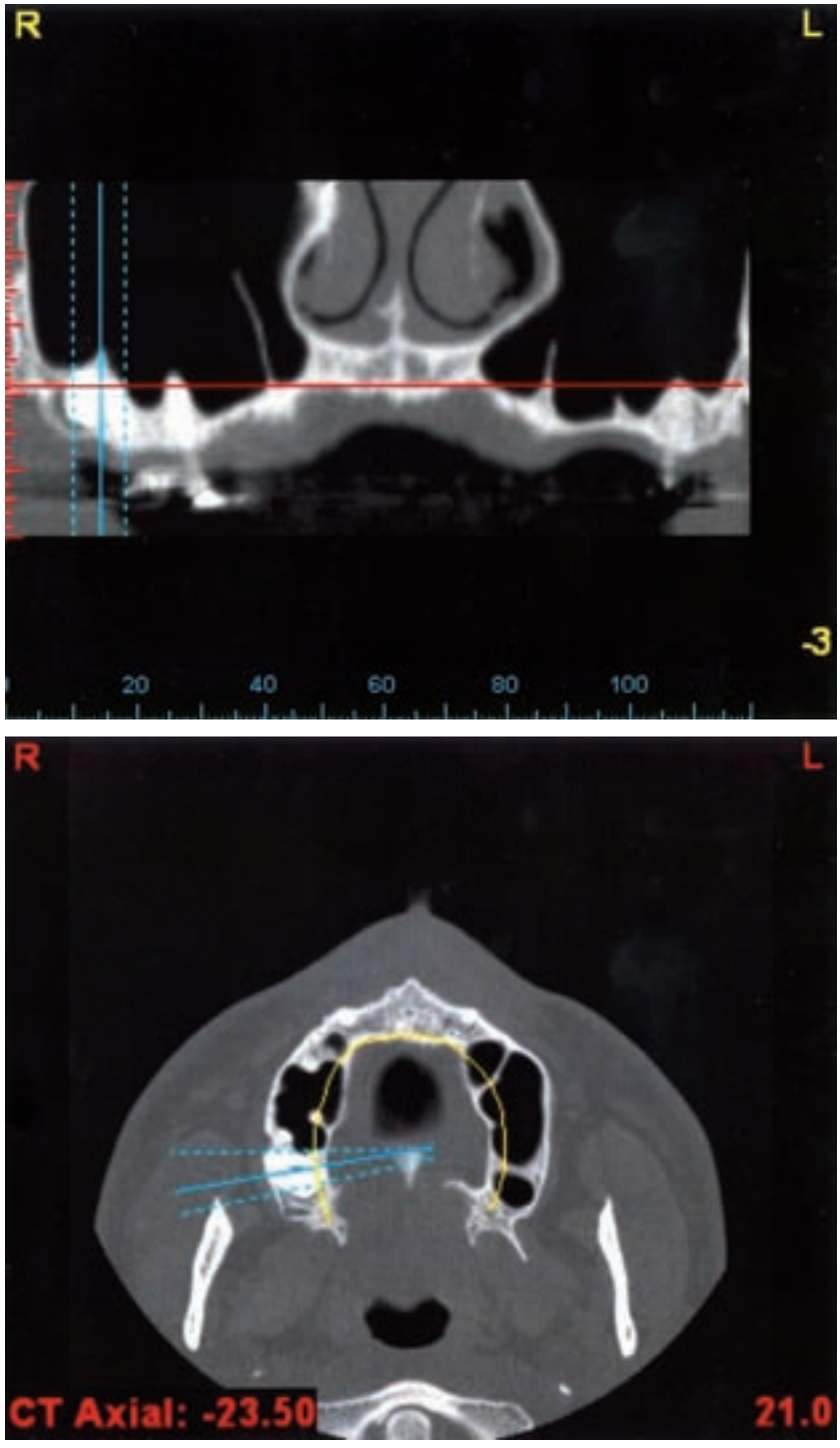


Fig. 16.12 (a) Septum in left sinus (panoramic DentaScan view). (b) Septum from (a) (axial 3D DentaScan view).

- Very small perforations may self-repair by membrane fold-over or clot formation.
- Large perforations will require large repairs for stability.
- Large repairs tend to tent apically when grafts are placed.
- Repair membranes placed next to the lateral wall tend to shift medially when graft is placed.
- Repair membranes that are soft and shapeless when wet are not ideal for large repairs.

Techniques for membrane repairs using collagen membranes have been published (28–33). Zijderveld *et al.* (7) and Shlomi *et al.* (33) preferred to use lamellar bone sheets for repairs owing the material's rigidity (7, 34). The following discussion is based on the paper by Testori

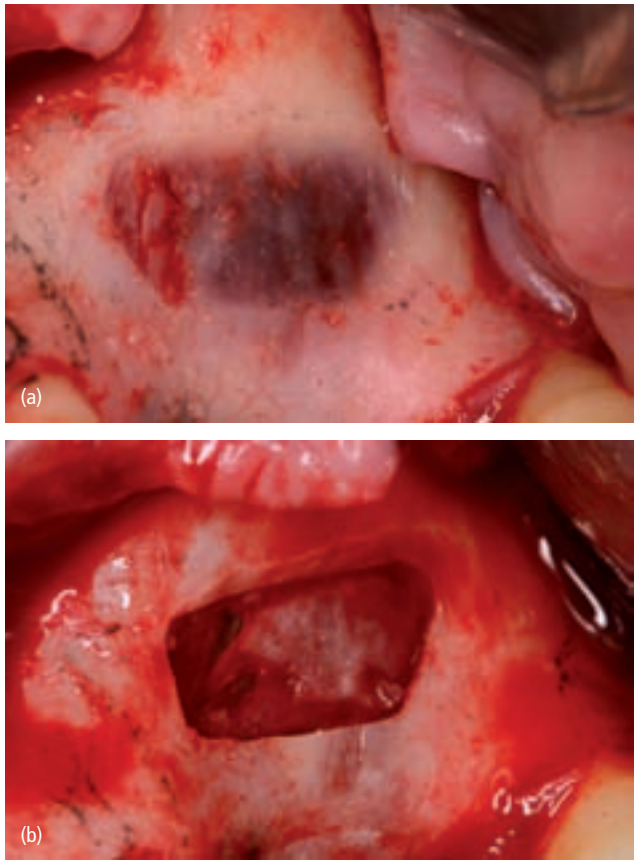


Fig. 16.13 (a) Sinus septum in the surgical field. (b) Septum removed via piezoelectric surgery.

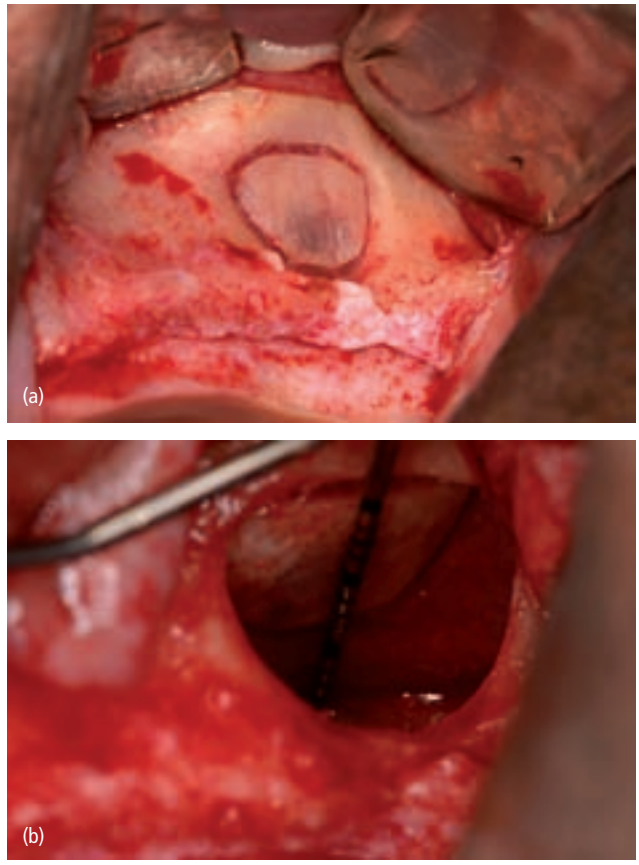


Fig. 16.14 (a) Thin window outlined with a piezoelectric diamond insert. (b) Thin window with hinge or "island" window elevated.

et al. (33), which presents four specialized repair techniques for larger perforations using bioabsorbable collagen barrier membranes.

It is not uncommon to perforate the Schneiderian membrane with rotary instruments (diamond burs) when performing a lateral window osteotomy. With careful membrane elevation, it is possible that these perforations will remain small. When the membrane elevation is completed, the small perforation will either disappear in the folds of the elevated membrane or, more likely, self-repair with a small blood clot. In this type of case a separate repair procedure is not indicated as the goal of graft material containment has been biologically achieved. If a very small perforation is still evident, it can be repaired with a PPP or PRGF fibrin repair or it can be covered with a soft repair membrane such as CollaTape (Sulzer Dental, Plainsboro, NJ, USA) or GelFilm (Upjohn Company, Kalamazoo, MI, USA).

If the perforation is larger (greater than 5 mm) one should use a membrane that retains its shape (BioGide; OsteoHealth, Shirley, NY, USA) or remains stiff when wet (BioMend; (Zimmer Dental, Carlsbad, CA, USA; or OsseoGuard; BioMet 3i, Palm Beach Gardens, FL, USA). The amount of stability that can be achieved with the repair is directly proportional to the amount of coverage over the intact portion of the sinus membrane. There is no reason not to consider making a new roof for the graft material compartment with the repair membrane since it has been shown in animal studies that the elevated Schneiderian membrane plays a minimal role in vascularization of and bone formation in the graft (35, 36). Figure 16.16 shows a repair membrane that forms a new roof in the graft material compartment. Note that it has been elevated to the horizontal position, demonstrating Schneiderian membrane release from the medial wall.

As perforations become still larger (rents or tears greater than 10 mm), non-stabilized repairs become unpredictable as they tend to shift medially while packing the graft material and may even rise upwards, through the tear, with partial or complete loss of the graft material into the sinus cavity. This untoward event may lead to blockage of the ostium, postoperative sinusitis, or a sinus infection. A major loss of graft material containment will necessitate a re-entry for removal of all particulate graft material.

Repair techniques have been developed to address both larger tears and tears in difficult locations. If, after

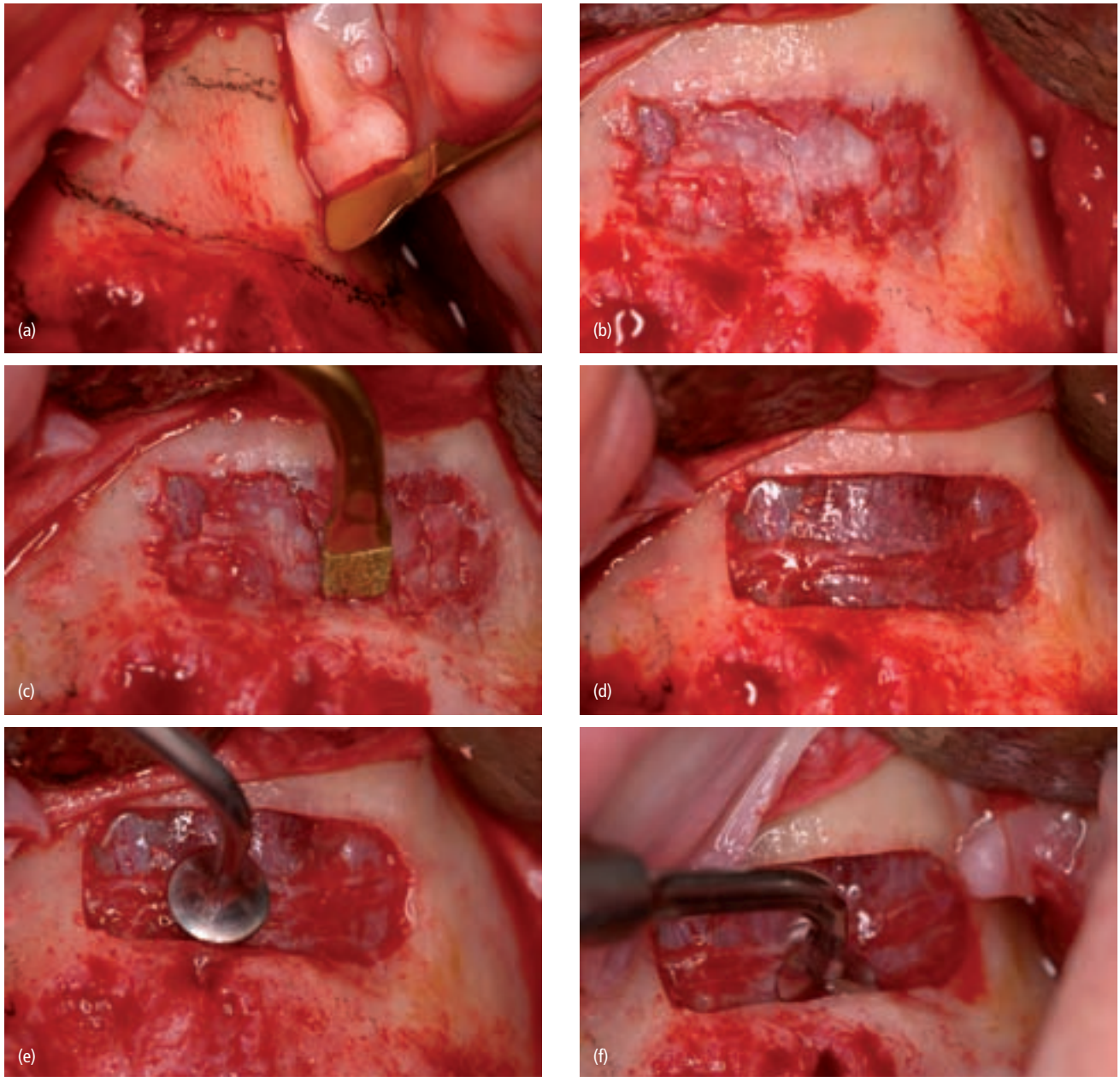


Fig. 16.15 (a) Thick lateral wall with osteoplasty insert in place. (b) Thick lateral wall reduced to fragments. (c) Window refined with diamond osteotomy insert. (d) Complete osteotomy exposing membrane. (e) Piezoelectric elevator in place. (f) Initial membrane elevation in progress.

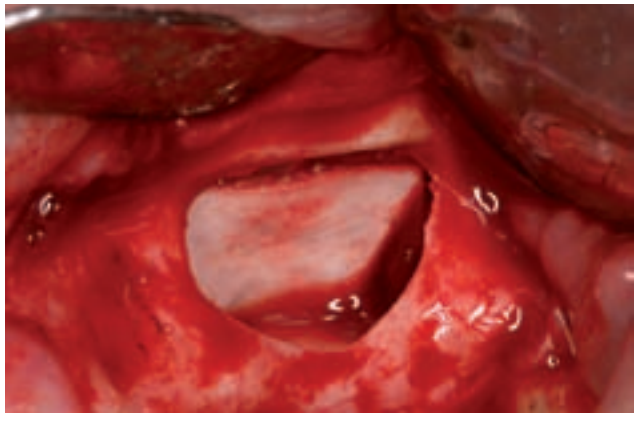


Fig. 16.16 Non-stabilized repair forming a new roof confining the particulate graft.

final membrane elevation, the perforation resides close to the superior aspect of the lateral wall window preparation, it is quite common for the repair membrane to drift medially while the particulate graft material is being placed. This is due to the convex shape of the lateral wall in the malar eminence (first molar) area, the upward tenting of the membrane when packing, and the likelihood that the repair membrane is not sufficiently wide to reach the medial wall. To counteract this shifting tendency, use a large membrane (usually an adjusted 20 × 30 mm size) and leave a portion of it outside the window folded in a superior direction (Fig. 16.17a, b). This is a simple repair modification that will prevent any medial and/or superior shifting of the membrane.

In some instances further stabilization can be achieved by a combination of the above-described folding technique with external tacking and/or internal suturing. Again, the membrane elevation must be completed to expose the bony walls and their vascular supply before completion of the repair. It must also be realized that the torn Schneiderian membrane is very fragile and all suturing must be accomplished with small needles with minimal tension on the remaining membrane. Most often, it is not possible to suture the tear completely closed. When this is the case, it is possible to use the sutures as struts upon which to rest the repair membrane. The sutures can course between two sections of torn membrane or between the membrane and small holes drilled in the lateral wall (Figs 16.18, 16.19). Figures 16.20(a, b) and 16.21 show evidence of radiographic and histologic success of the repair procedure after 9 months.

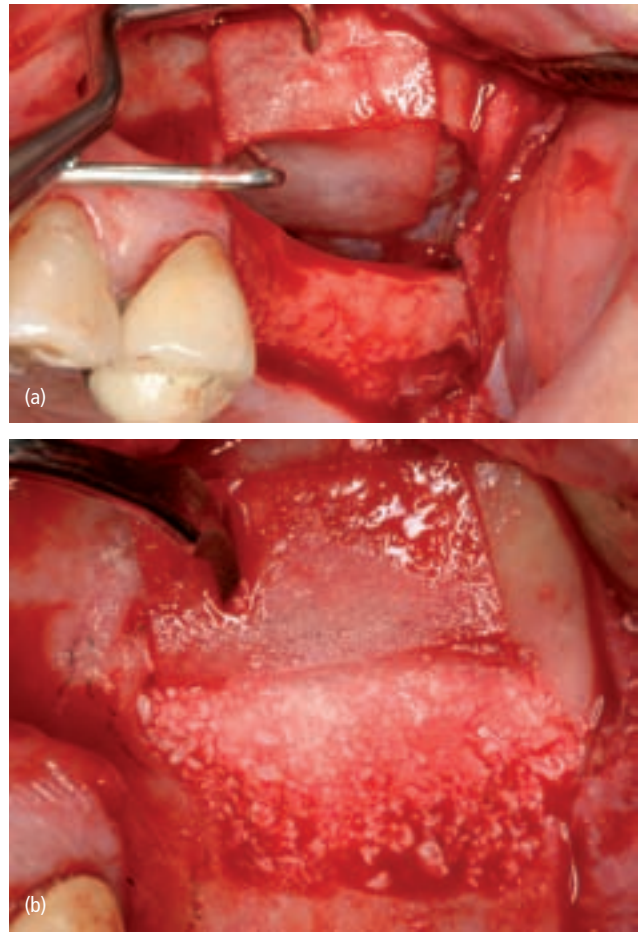


Fig. 16.17 (a) Repair membrane stabilized by folding outside the window. (b) Graft material in place.

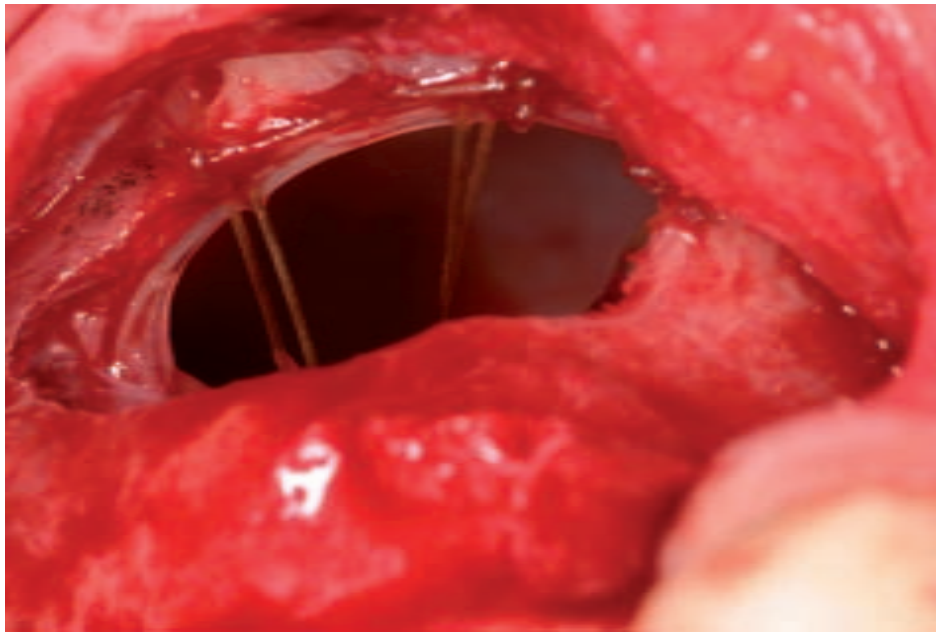


Fig. 16.18 Suture repair from a torn sinus membrane to holes made in the lateral wall.

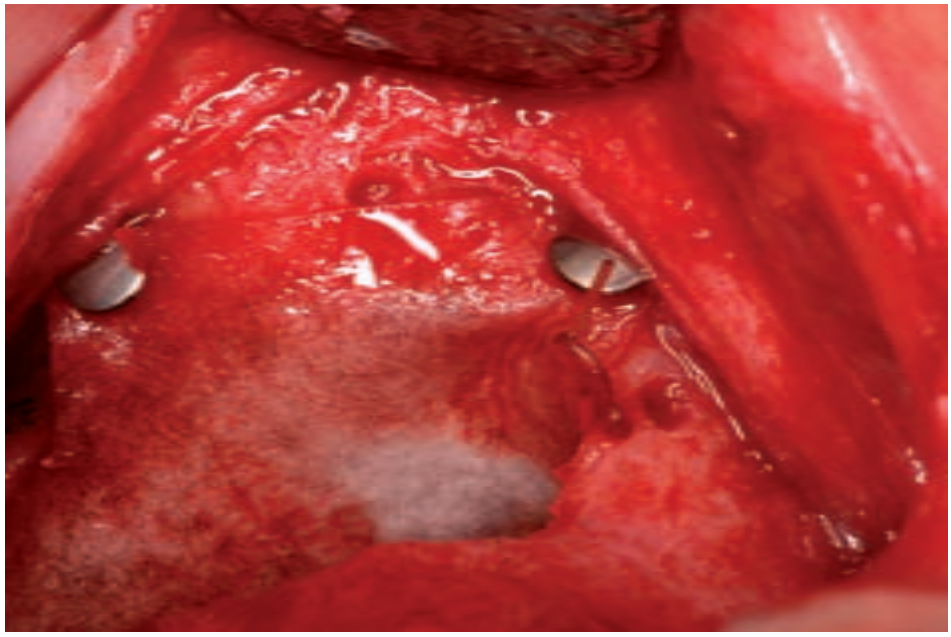


Fig. 16.19 Membrane resting on suture struts with additional fold and tack stabilization.

In extreme situations there may be insufficient membrane fragments remaining to retain a suture. At this point a decision has to be made as to whether to abort the procedure or perform a more extensive repair. In the following case (Figs 16.22–16.26) the Loma Linda pouch technique (31) was used, along with additional stabilization tacks (33) to create a complete container for placement of the graft material. A large 30 × 40 mm BioGide membrane (Geistlich, Wolhusen, Switzerland) was pushed through the window to create an internal sinus pouch to hold and confine the graft material. The edges of the membrane were left outside the window to hold it in position. Two tacks were also required to keep the entire membrane from slipping inside the sinus and through the perforation.

There is a relatively large literature base pertaining to implant survival following perforation and repair of the sinus membrane. Papers by Jensen (37) (report of the sinus consensus conference of 1996), Proussaefs (27), and Khoury (38) state that implant survival is negatively affected by membrane perforations. Hernández-Alfaro *et al.* (39) report that the implant survival rate is inversely proportional to the size of the membrane perforation. Other authors present data showing that survival rates are not affected by perforations (15, 33, 34, 40, 41). The latter has been the experience at the New York University Department of Periodontology and Implant Dentistry when proper repairs are made and they remain intact throughout the postsurgical healing period.

The presence of a bioabsorbable repair membrane against the elevated Schneiderian membrane does not impede the blood supply to the graft as the reflected Schneiderian membrane does little to provide a blood supply. The Loma Linda pouch technique, however, presents a theoretical problem in that the repair membrane completely surrounds the graft and is likely at least to delay the vascularization of the graft from the lateral sinus walls. The vital bone formation in the two cases presented above was 30% and 32% by volume, respectively, which is considered a favorable result when using 100% xenograft. The Testori paper (33) presents results from 20 cases with large perforation repairs. All patients had minimal postoperative symptoms and all cases showed clinical, histologic, and radiographic evidence of successful sinus elevation with 100% implant survival.

If repair procedures do not appear to give a stable result, it may be necessary to abort the grafting procedure and allow the sinus membrane to heal. A reasonable waiting time, confirmed by ENT physicians, should be in the vicinity of 4 months; 2 months for smaller perforations. Should this be the treatment of choice, the placement of a bioabsorbable barrier membrane over the window should prevent soft-tissue encleftation into the sinus cavity. It will be necessary to perform a split-thickness re-entry flap over the window owing to the likelihood that the periosteum may be joined to the newly formed Schneiderian membrane in the window area. The residual small amount of soft tissue is then elevated along with the Schneiderian membrane to create the roof of the graft material compartment. This can be covered with a bioabsorbable collagen barrier membrane to isolate this small amount of connective tissue from the graft, but there is no evidence as to the necessity of this procedure.

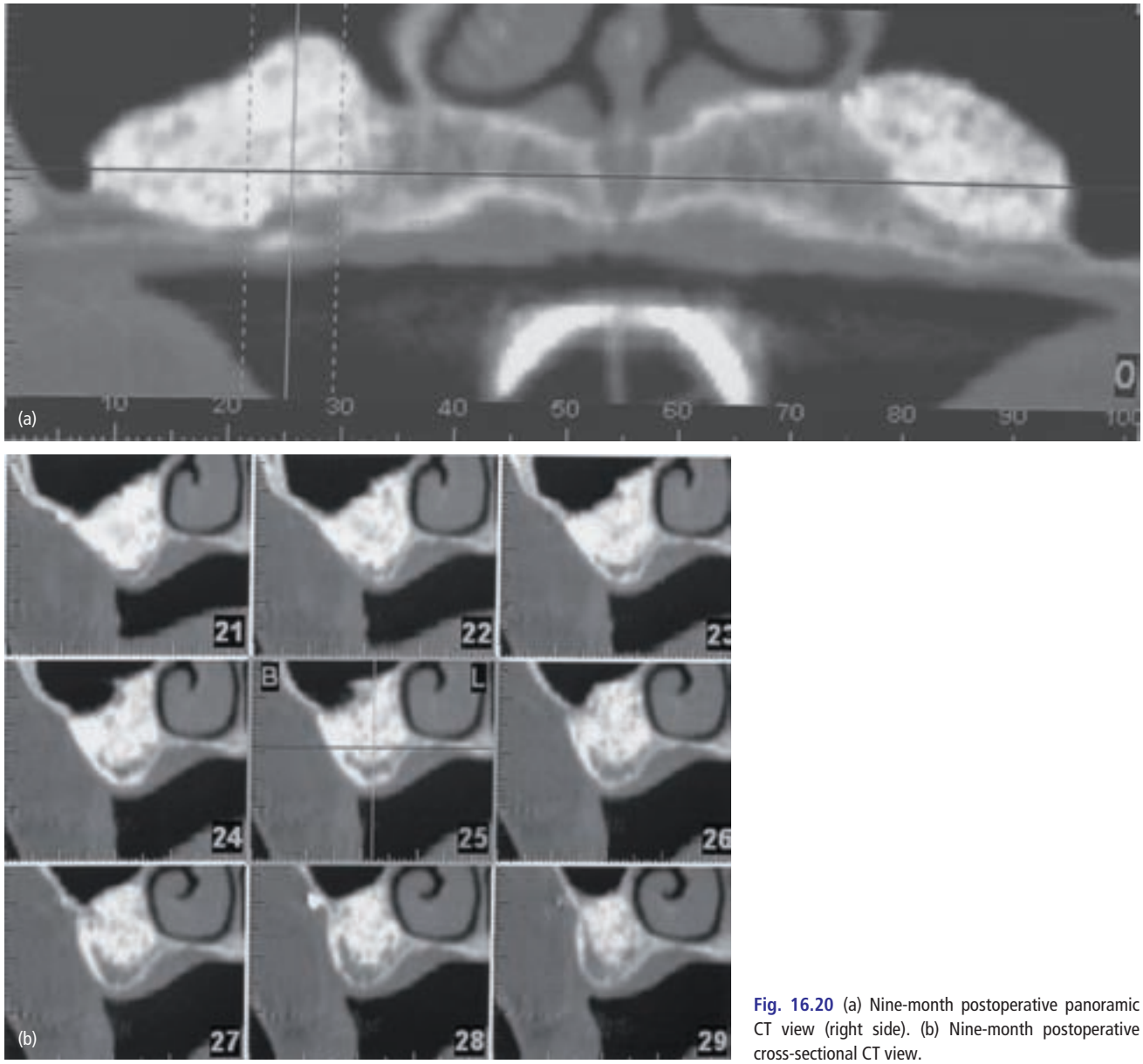


Fig. 16.20 (a) Nine-month postoperative panoramic CT view (right side). (b) Nine-month postoperative cross-sectional CT view.

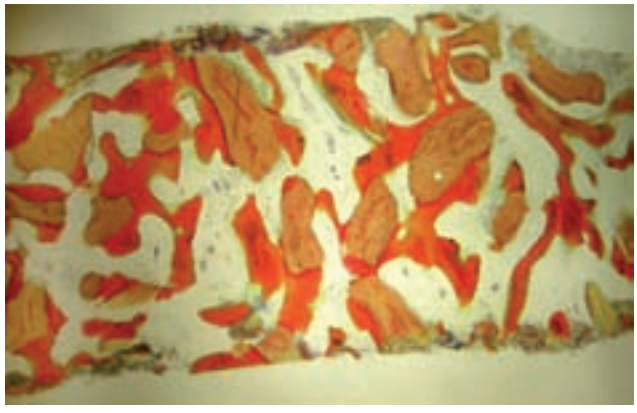


Fig. 16.21 Nine-month histology.

Take-home hints

- Perform presurgical diagnosis with CT scans to disclose difficult anatomy.
- Make the window in the best location (3 mm from the floor and anterior wall).
- Use piezoelectric surgery for lateral osteotomy and initial membrane elevation.
- Elevate the membrane from lateral to medial, keep the instrument on bone at all times.
- Use a repair membrane that remains rigid when wet to achieve the most stable repair.
- All repairs must be stable.

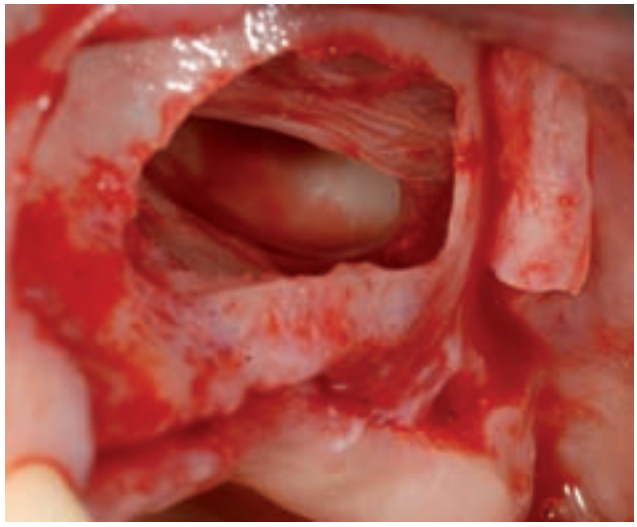


Fig. 16.22 Large membrane tear.

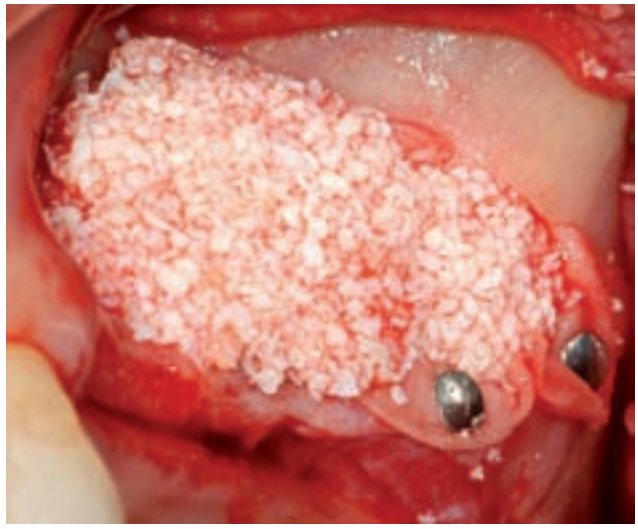


Fig. 16.24 Particulate Bio-Oss graft in place.

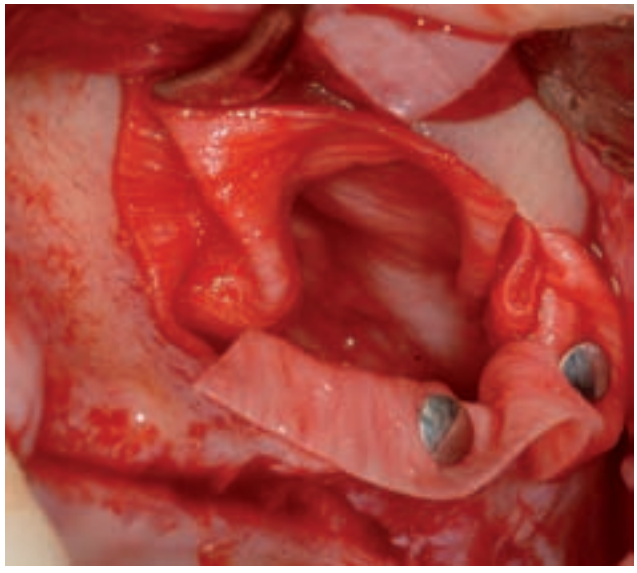
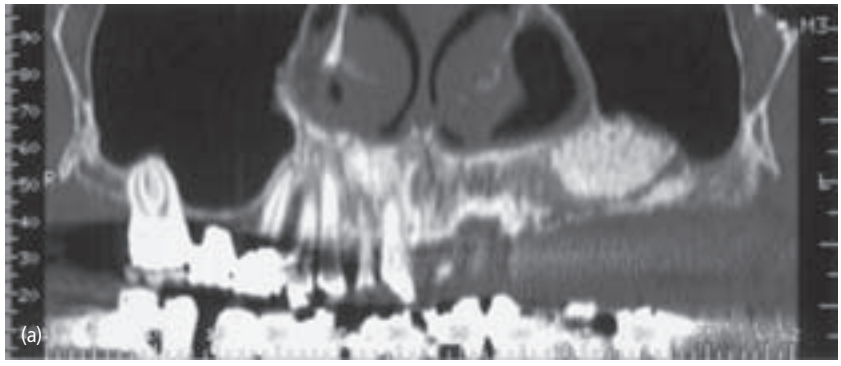


Fig. 16.23 30 × 40 mm BioGide membrane in position.



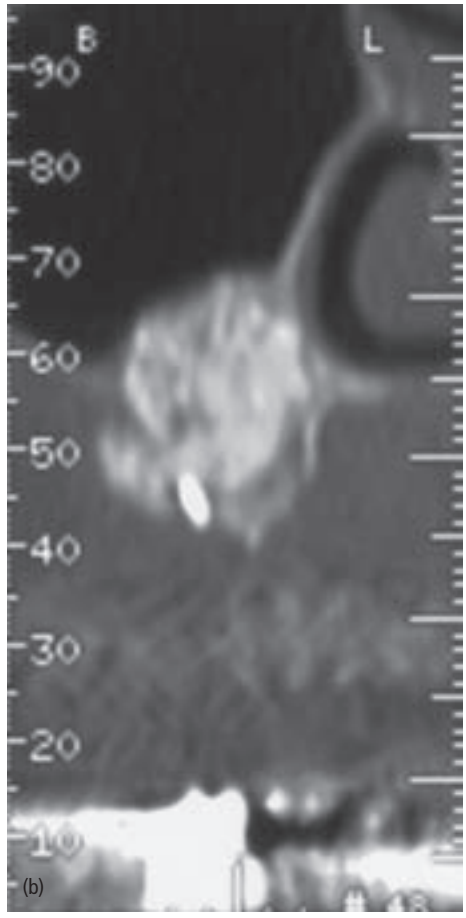


Fig. 16.25 (a) Six-month postoperative panoramic CT (left side). (b) Six-month postoperative cross-sectional CT.

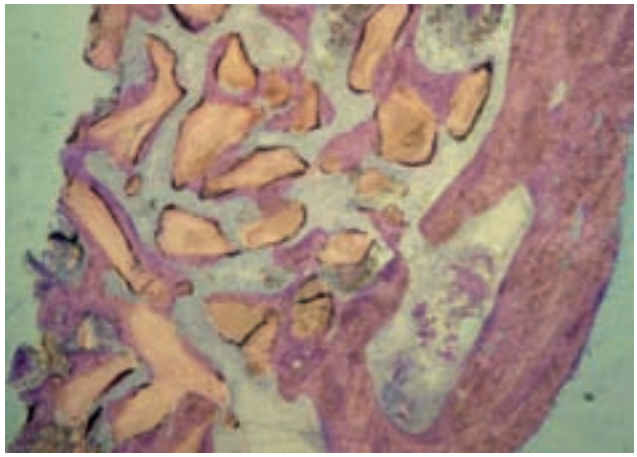


Fig. 16.26 Six-month histology.

Fig. 16.27 Location of the infraorbital foramen on a dry skull specimen.

Other intraoperative complications

Complications such as tears in the buccal flap and injury to the infraorbital nerve generally result from poor surgical technique.

Buccal flap tears may result from attempts to release the flap to achieve primary closure. This is usually an unnecessary procedure in a typical sinus elevation. Since there is no change in external dimensions, the flap will close tension free without release. This is more often a problem when simultaneous ridge augmentation is performed. Be aware of the possibility that the flap may be thin in the area of release and that the direction of the bone surface changes in the area of the malar eminence.

Blunt or pressure injury to the infraorbital nerve may result during flap retraction. If the flap extends superiorly to this position, the exit of the nerve from the bone should be visualized and retraction placed distal to it. It is also possible to injure this nerve during sharp dissection to release the flap for primary closure. The exit-point of the nerve from the skull is just below the infraorbital notch. Location of this anatomic structure is crucial before performing these procedures (Fig. 16.27).

In cases of severe maxillary atrophy it is possible to find the nasal passage in a location where one would expect the maxillary sinus. The preoperative DentaScan will show that there is no residual crestal bone and that the proposed restoration is not below the sinus, but beneath the nasal passage (Fig. 16.28). The postoperative

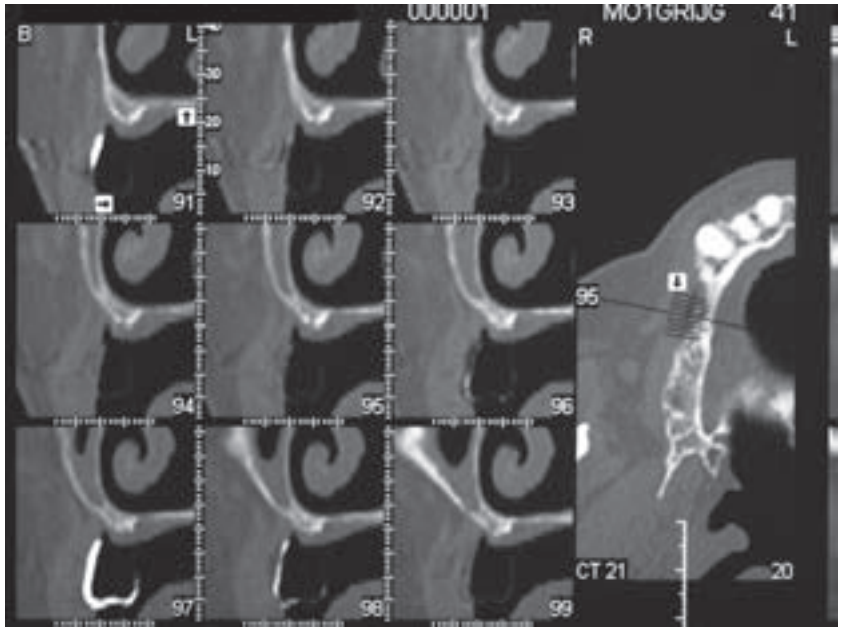


Fig. 16.28 Cross-sectional CT-scan view indicating that the proposed restoration is not below the sinus.

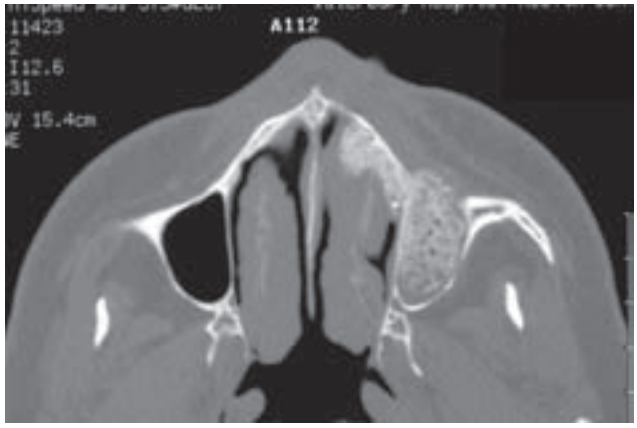


Fig. 16.29 Postoperative axial view showing the graft in both the sinus and the nasal passage.

axial view shows that, in addition to a posterior sinus graft, the nasal passage has been grafted (Fig. 16.29). In this case no remedial therapy was advised as the ostium remained patent and the nasolacrimal duct was undisturbed. This sinus was grafted with Puros allograft. The entire graft (nose and sinus) resorbed and only the sinus was regrafted 14 months later.

Postoperative complications

Postoperative edema, ecchymosis, mild to moderate discomfort, minor nosebleed, minor bleeding at the incision line, and mild congestion are within the scope of expected patient responses to this procedure. Some are due to manipulation of the facial flap and others to the manipulation of the sinus membrane.

Major postoperative complications after sinus elevation surgery are relatively uncommon. They include graft infections, sinus infections, postoperative sinusitis, profuse postoperative bleeding, flap dehiscence, oroantral fistula formation, formation of inadequate graft volume for implant placement, loss of graft material containment as a result of either sinus membrane rupture or exfoliation of graft material through the sinus window, maxillary cyst formation (42, 43), migration of dental implants into the sinus graft or into the sinus cavity proper, and the failure of dental implants.

In a prospective study of 100 consecutive sinus elevations, Zijderveld *et al.* (7) reported an 11% incidence of membrane perforations and a 2% incidence of bleeding as intraoperative complications. The postoperative complications listed in order of most frequent occurrence were loss of implants (4%), wound dehiscence (3%), graft infections (2%), postoperative maxillary sinusitis (1%), and loss of or inadequate graft volume (1%).

While postoperative complications are relatively infrequent, understanding how to cope with them may be vital for the ultimate success of the procedure.

Postoperative infection

Etiology and incidence

Postoperative infections are relatively infrequent, with infection rates reported between 2% and 5.6% (5, 7, 15, 44), with no distinction being made between true sinus and sinus graft infections. The incidence can be reduced by proper case selection (preoperative diagnosis) and sound surgical techniques that incorporate infection control. When infections are suspected, therapy should be rendered quickly, as a true sinus infection can become a pan-sinusitis if treatment is delayed or handled improperly.

Infections after sinus elevation surgery can occur in two locations. Most commonly the infection is not a true sinus infection but an infected sinus graft. It should be realized that the sinus graft is not actually in the sinus, but is located below the elevated sinus membrane, hence the term subantral augmentation. True sinus infections are less common but may have more widespread consequences such as a pan-sinusitis which can occur as a result of the interconnectivity of the sinus network.

Etiology of sinus infections

The etiology of postoperative sinus infections can arise from two general sources. The first is a previously existing asymptomatic chronic sinus infection exacerbated by postoperative inflammatory changes. The second source is from a communication, through a perforation, with bacteria from the oral cavity or bacteria originating from periapical or periodontal infections.

Pre-existing inflammatory sinus disease may, under less than ideal conditions, be a factor in the etiology of postoperative sinus infection. Patients with a preoperative diagnosis of, or symptoms of, acute sinusitis or acute chronic sinusitis should be referred for appropriate therapy and medical clearance before sinus elevation surgery. This may be in the form of antibiotic therapy (levaquin or augmentin are appropriate), combined antibiotic and anti-inflammatory therapy [one such regimen might include augmentin (amoxicillin–clavulanic acid 825 mg/125 mg) twice daily or omnicef 300 mg twice daily for 21 days and prednisone 40 mg for 3 days, 20 mg for 3 days, 10 mg for 3 days], or it may require endoscopic sinus surgery to remove pathologic tissues or to widen the ostium to create more favorable drainage.

The most common conditions that lead to acute sinusitis are blockage of the osteomeatal complex, inflammatory changes resulting from tooth related problems (endodontic or periodontic), and allergy-related inflammatory changes. Large mucous retention cysts (pseudocysts) may also result in compromised drainage; however, these lesions are unlikely to respond to antibiotic or anti-inflammatory medications. Pseudocysts become problematic when they are elevated during

sinus grafting and, as a result, block sinus drainage through the ostium. The likelihood of this outcome can be detected by performing a preoperative CT analysis. The presence of pseudocysts is readily detected and they can be diagnosed as not a problem (small volume), a problem that can be handled at the time of surgery by drainage with a large gauge needle, or a problem that must be treated before sinus elevation by endoscopic surgery. It is prudent to refer the patient to an ENT specialist to diagnose and treat these conditions before sinus augmentation surgery. A healthy sinus with a thin membrane and patent ostium is shown in Fig. 16.30. Figure 16.31 shows a relatively small mucous retention cyst on the medial wall of the sinus that was drained at the time of augmentation surgery.

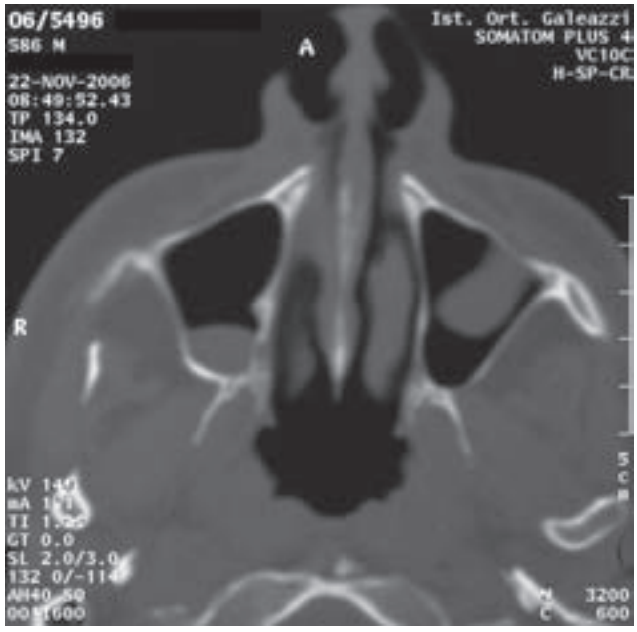
In cases where inflammation and/or infection of known etiology is present (periodontal, periapical, allergic), presurgical antibiotic/anti-inflammation therapy will in many cases resolve the problem before augmentation surgery. Figures 16.32–16.34 show that the etiology of the sinus disease was the infected molar teeth. These were removed and the patient was placed on a course of augmentin and prednisone therapy leading to almost complete resolution

Sinus elevation surgery will, in general, result in a short-term inflammatory reaction in the sinus, compounding any previously existing pathology. This response has been observed when bone morphogenetic proteins (BMP-2) are used as part of a sinus graft as cellular responses increase dramatically. The response is short lived and will resolve without therapy (Figs 16.35–16.37).

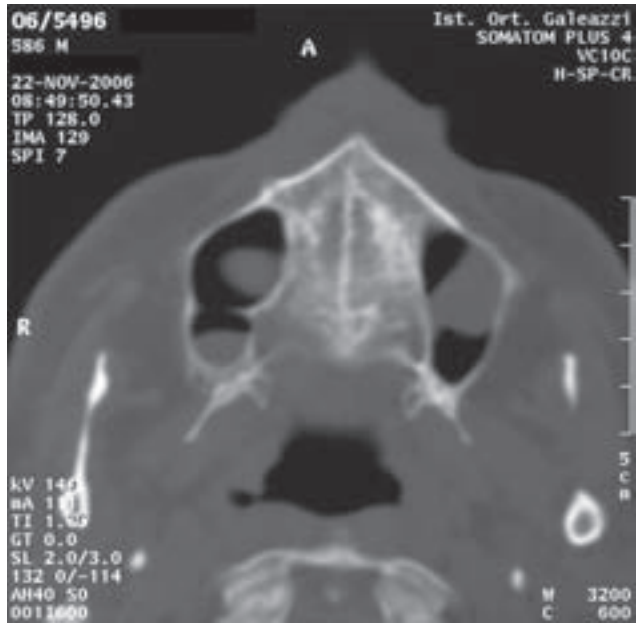
Fig. 16.30 Healthy sinus with a patent ostium high on the medial wall.

Etiology and incidence of infected sinus grafts

This is the most common form of infection after sinus elevation surgery. The incidence of postoperative sinus graft infections has not been separately documented but, by inference, the incidence is approximately 2–5%. The most common symptoms may include tenderness, nasal obstruction, pain, swelling, fistulation, purulent discharge, flap dehiscence, and suppuration. Increased intrasinus pressure may be a secondary factor which



(a)



(b)

Fig. 16.31 Mucous retention cyst (pseudocyst) on right and left medial walls (axial CT view).

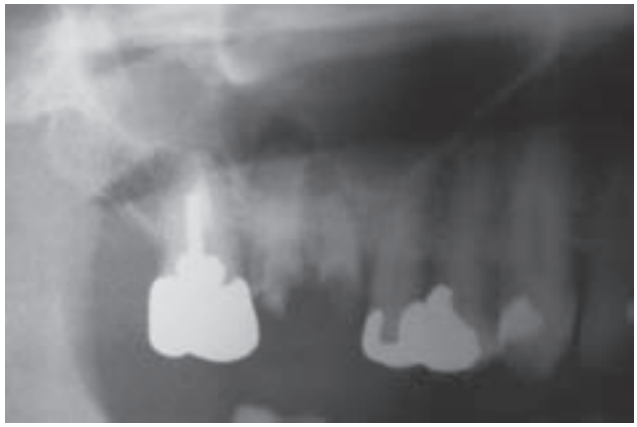


Fig. 16.32 Hopeless molars in a panoramic view.

may result in blocked sinus drainage. Symptoms may appear soon after therapy (within 2 weeks) or may first appear after a few months sometimes, but not always, preceded by vague symptomatology. Figures 16.38–16.40 present a typical CT-scan appearance of a late (2-month) postoperative infection. A somewhat common appearance is that of a "black hole" in the central portion of the graft with a radiopaque dome over the graft. All three views show what appears to be an undisturbed layer of graft material (normal dense opacity) surrounding the infected core. Upon open débridement this core feels quite solid and is not easily removed.

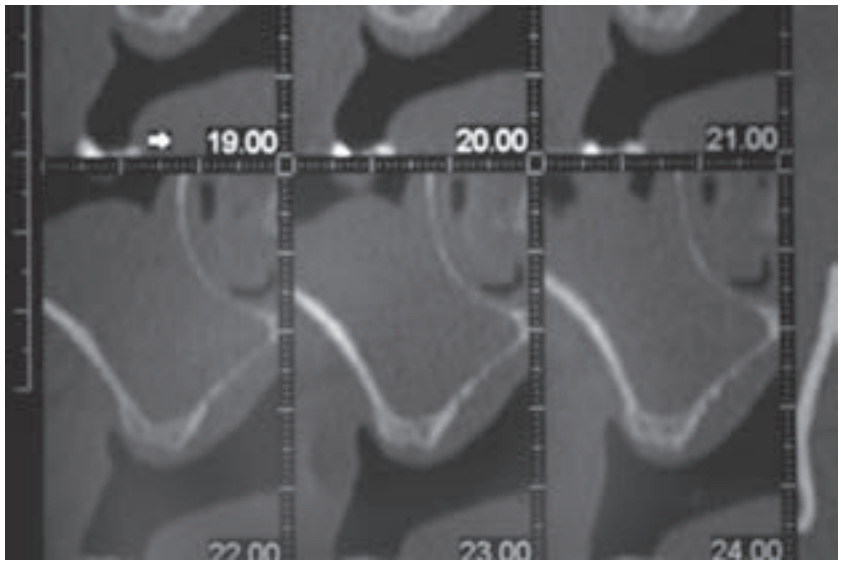


Fig. 16.33 CT scan after extraction of the molars.

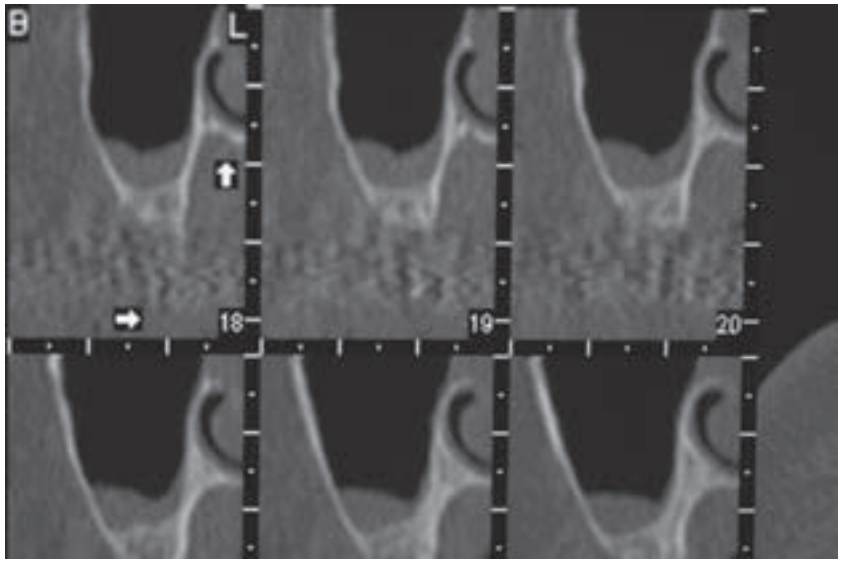


Fig. 16.34 CT scan 2 months after Augmentin/prednisone therapy.

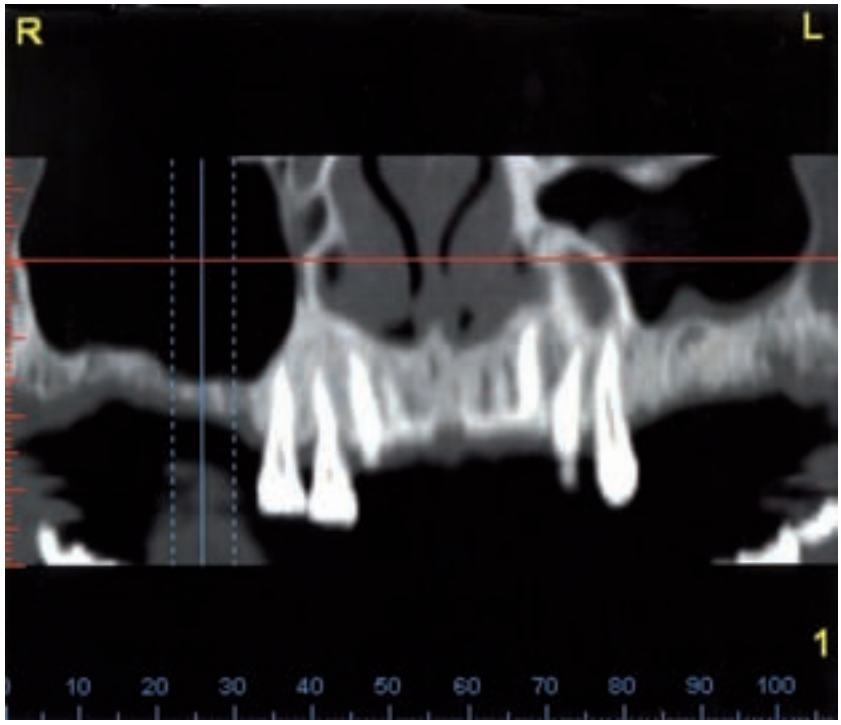


Fig. 16.35 Preoperative sinus.

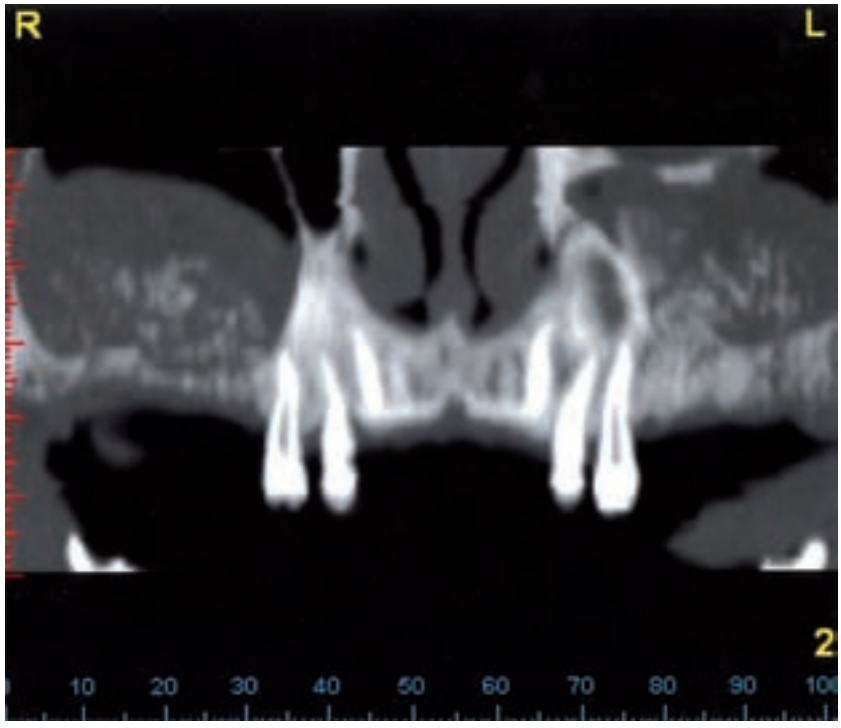


Fig. 16.36 One week after sinus grafting.

Sinus graft infections may be caused by:

- pre-existing sinus infection (should not treat symptomatic patient)
- contamination of the surgical site:
  - salivary/bacterial contamination of the graft material, instruments, or membrane
  - untreated periodontal disease
  - adjacent periapical pathology
  - lapses in the chain of sterility
  - extended surgical time
- infected simultaneous lateral ridge augmentation procedures.

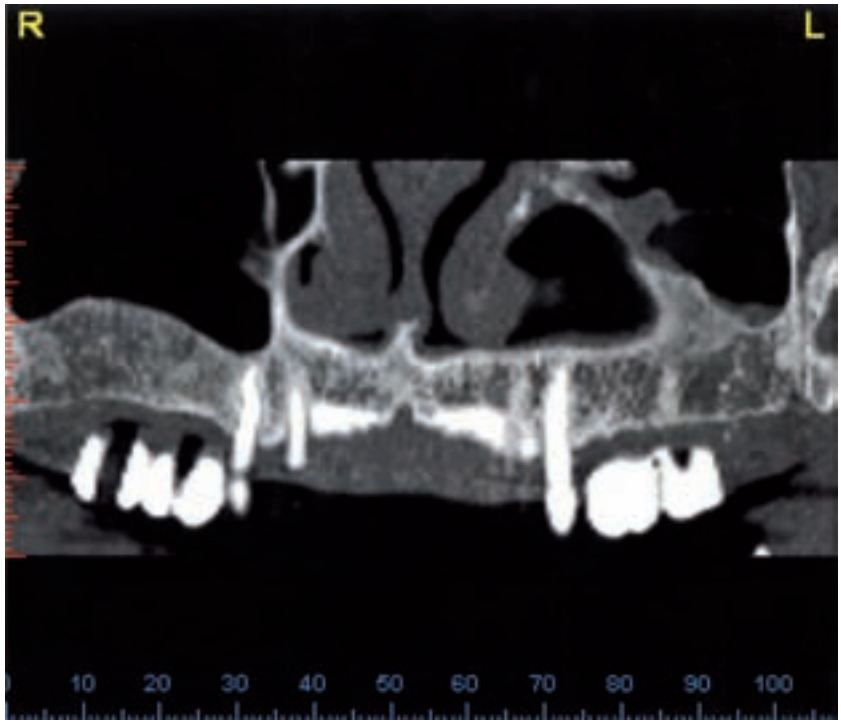


Fig. 16.37 Four months after sinus grafting (no therapy rendered).

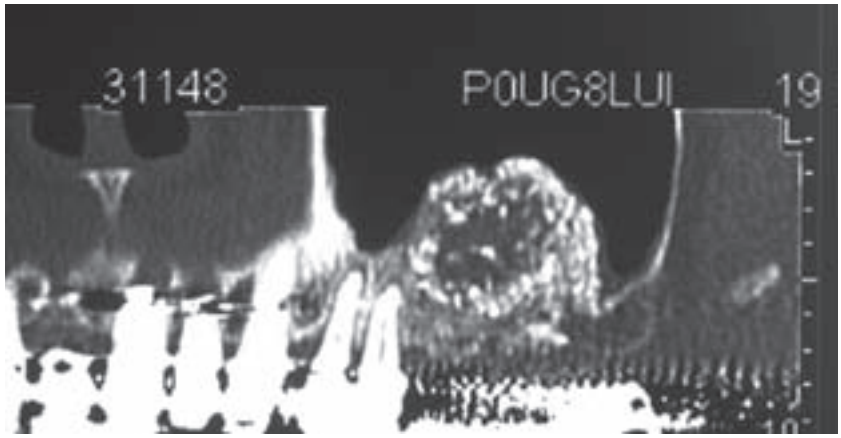


Fig. 16.38 Panoramic CT view of an infected sinus graft showing "black hole".

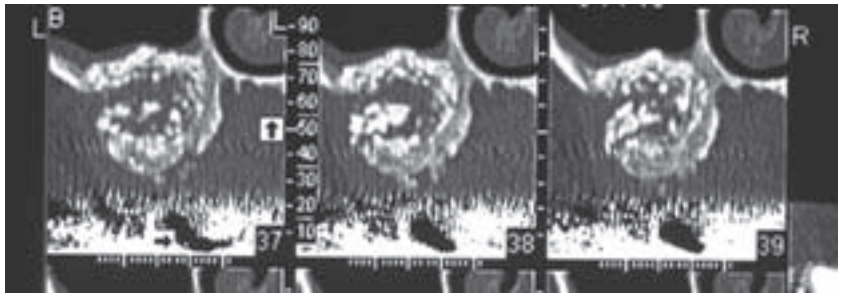


Fig. 16.39 Cross-sectional CT view showing a buccal drainage tract.

Prevention of sinus graft infections

As an infected sinus graft can be a catastrophic event for a patient in terms of morbidity, additional therapy, increased treatment time, and possible systemic complications, all efforts should be made to prevent this untoward outcome.

Preoperative diagnosis of potential sources of graft infection is invaluable. Pre-existing periapical pathology, when the apices of infected teeth are in or close to the sinus, produces a reaction in the sinus that may be one of inflammation and/or bacterial contamination (Fig. 16.41). When the membrane is elevated these bacteria are

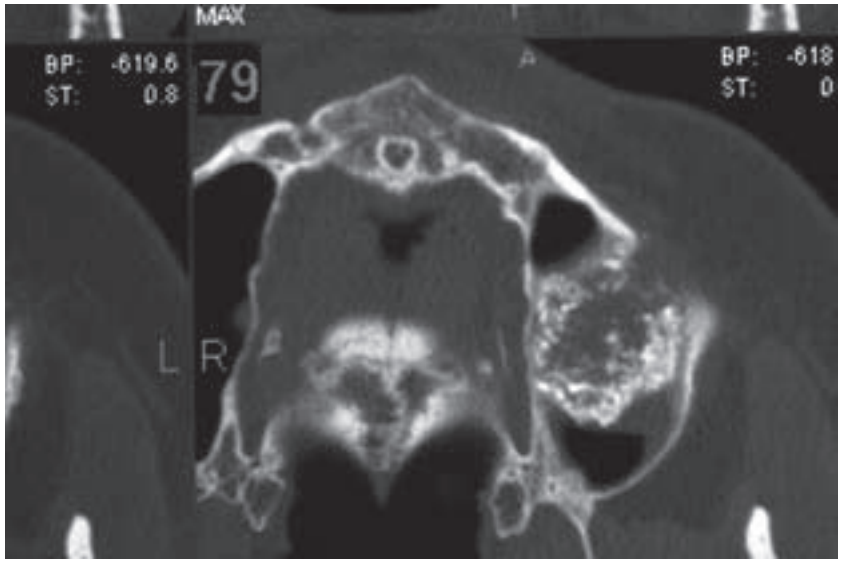


Fig. 16.40 Axial CT view showing an infected core with surrounding graft.

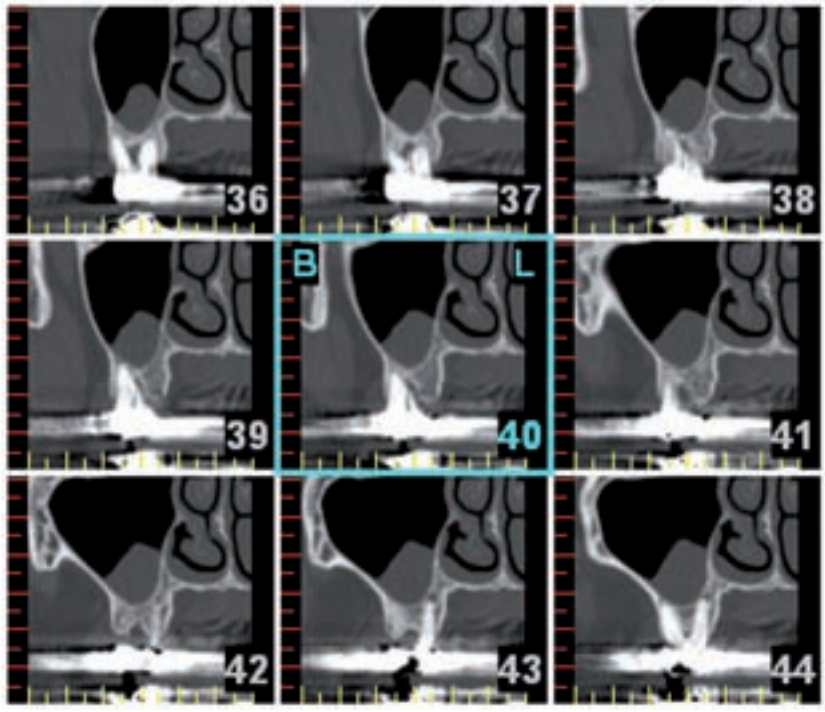


Fig. 16.41 Periapical pathology extending into the sinus.

immediately within a bone graft placed in a confined space; an ideal incubator. Localized endodontic and periodontal therapy should be completed before sinus grafting, or the hopeless teeth should be extracted.

Simultaneous extraction of teeth that penetrate the sinus floor may open a pathway to infection as the sinus graft is immediately connected to the oral cavity through the extraction socket which may or may not be covered by flap release and primary closure.

Sinus grafts with simultaneous ridge augmentation procedures are a further extension of the above extraction socket scenario. Barone *et al.* (44) reported on 124 sinus elevations, 26 with simultaneous lateral ridge augmentations. The infection rate was 3% for the sinus graft-only group ($n = 98$) and 15.4% for the group that had simultaneous ridge augmentations ($n = 26$). Five of the seven infections occurred in smokers. The cause of the infection in these cases and in other ridge augmentation studies has been attributed to the breakdown of primary soft-tissue closure over the grafted site with exposure of the barrier membrane and subsequent graft infection. One should note that in a ridge augmentation procedure

the incision line is directly over the barrier membrane, while in a properly designed sinus graft the membrane should be distant from the incision line. Soft-tissue healing appears to be affected in a negative way by smoking, but smoking alone has not been shown to be a negative factor in pure sinus grafting procedures. In a study by Levin *et al.* (45) onlay bone grafts had a higher complication rate in smokers than non-smokers but there was no such relationship present in pure sinus lift grafts.

Prophylactic procedures play an important role in prevention. Many antibiotic regimens have been recommended. In the author's experience amoxicillin–clavulanate (Augmentin) is the drug of choice. The spectrum is greater than that of amoxicillin or ampicillin owing to the presence of clavulanic acid, which is active against β-lactamase-producing bacteria. Augmentin 825/125 twice daily for 7 days (starting the night before surgery) is an effective prophylactic dose. Historically, clindamycin (Cleosin) has been recommended for penicillin-allergic patients. However, some clinicians feel that clindamycin is not the ideal prophylactic antibiotic for these patients. In this author's experience, in more than 15 years of sinus grafting, more than 95% of observed or reported infections occurred in patients taking prophylactic clindamycin. The author has used levofloxacin (Levaquin) or moxifloxacin (Avelox), second and third generation bactericidal quinalone drugs, with much more favorable results. As there have been numerous reports of Achilles tendon rupture following use of fluoroquinalones, espeically when used in conjunction with steroids (46), the use of Zithromax or Biaxin may be an alternative for penicillin allergic patients. In general, the sinus graft infection rate appears to be higher in penicillin-allergic patients. An unrelated study reported an infection rate 3.3 times higher after immediate implant placement when Amoxicillin could not be used owing to a history of allergy (47).

The following recommendations are given as measures to reduce the incidence of postoperative infection:

- Proper case selection.
- Use proper prophylactic antibiotics.
- Use chlorhexidine and/or betadine preparation of the mouth and face for surgery.
- Use sterile draping with an infection control protocol.
- Periodontal and endodontic problems should be attended to before surgery.
- Keep incision lines distant from window and barrier membrane.
- Prevent contamination of graft and barrier membrane with saliva.
- Ensure the sterility of all instruments being used.
- Keep the surgical time as short as possible.
- Use postoperative chlorhexidine rinses.

Treatment

Treatment of sinus and sinus graft infections should begin immediately after symptomatology is recognized. The most common symptom is swelling over the lateral window site. Other symptoms include localized pain and/or tenderness, fistula formation, flap dehiscence, suppuration, and discharge from the nose or throat.

Sinus graft infections usually occur within the first 2 weeks after therapy. Late infections (1–2 months) occur less frequently. In general, infections are quite evident with reported patient discomfort and observed clinical swelling. Sometimes the symptoms are less evident with drainage occurring through a small fistula in the area of the lateral window. On other occasions the symptoms are so mild (non-specific mild discomfort) that the diagnosis is delayed for up to 1 month or more.

Early treatment is essential as the partial or total loss of the graft is a possible negative outcome. Other negative outcomes include pan-sinusitis, which may result in hospitalization, the occurrence of an oroantral fistula which will require surgical correction, and the development of chronic sinusitis.

Treatment can generally be described as involving three stages, each more invasive than the last, which are performed sequentially, as needed, until the infection resolves:

1. Reinstitute or change antibiotic therapy.
2. Insert drain with antibiotic therapy.
3. Surgical débridement with thorough flushing with sterile saline.

Without a microbiologic assay, immediate therapy is directed toward the most common causative pathogens and the common resistant strains of bacteria. The antibiotics chosen should be able to achieve high tissue concentrations in the inflamed sinus tissues.

If signs of infection are noted, it may be appropriate to change from the antibiotic used in prophylaxis to one with a broader or different spectrum. Metronidazole, a member of the nitroimidazole group, may be included for its bactericidal effect against Gram-positive and Gram-negative anaerobic bacteria. It must be used with an additional antibiotic (Augmentin or Levaquin) that is effective against aerobic bacteria.

A culture can be taken to obtain information should the infection be resistant to the chosen antibiotic. In many instances, however, it is difficult to obtain a culture that is not contaminated by oral bacteria.

If a Penrose drain is placed, it is more appropriate to place it in a location that is not directly over the graft. Placing the drain through an incision over the window and graft site may increase the potential for oroantral fistulation. Figure 16.42 shows the placement of a Penrose drain in an existing fistula. The drain was left in place for 3 days, and after removal, the infection resolved.

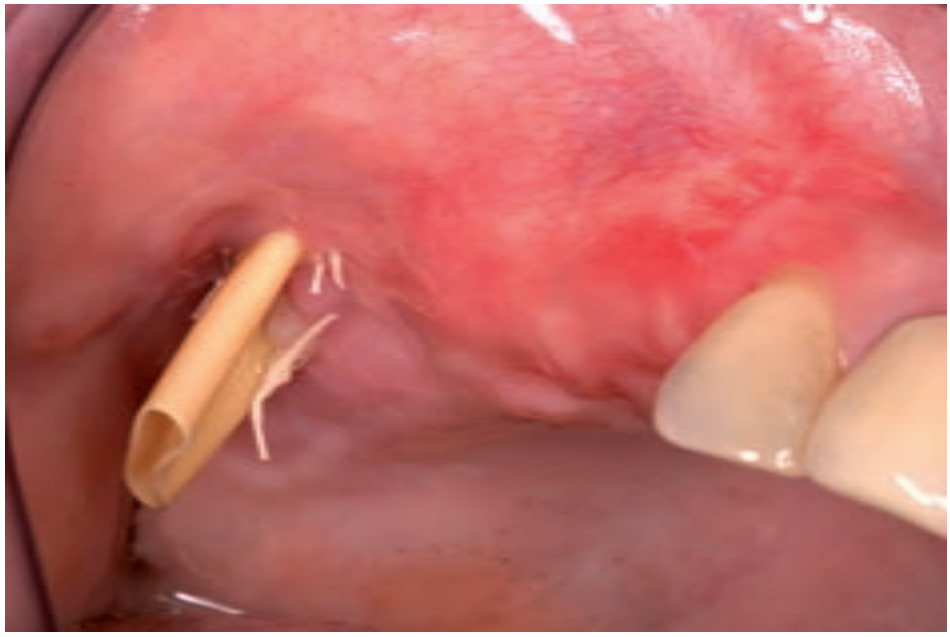


Fig. 16.42 Penrose drain in place.

If the infection does not respond to either of the above therapies, débridement of the infected graft material may be the only remaining means of infection control. All graft material can be removed followed by thorough flushing of the subantral space. Regrafting at the time of débridement is an option when signs of infection are minimal, but the risk of reinfection may be increased. It is usually advisable to wait until symptoms are no longer present before retreatment.

In cases of late infections that present as Figures 16.38–16.40 above, an alternative therapy to complete débridement may be considered. Attempting to remove the hard shell surrounding the infected central portion of the graft will probably result in destruction of the surrounding Schneiderian membrane. To avoid this, some clinicians have, on occasion, left this shell in place after thorough débridement and irrigation of the central portion of the graft (unpublished). The area is left to heal and the area is regrafted, possibly with simultaneous implant placement at 6–9 months. A split-thickness flap may be required to separate the mucoperiosteal flap from the Schneiderian membrane at the time of re-entry as the flap and membrane will be joined. Placing a barrier membrane over the window at the time of infection therapy may prevent this from happening, but the newly formed Schneiderian membrane may still be quite thin and fragile. This technique has been performed successfully on a limited number of cases but, without sufficient documentation, one must consider the risk of leaving a residual of contaminated material.

Take-home hints

- Ensure proper case selection and good surgical protocol to prevent infections.
- Treat early when infection suspected.
- Change the treatment if no response.

Postoperative sinusitis

Etiology

By decreasing the size of the sinus, maxillary sinus floor elevation has the potential to create more favorable drainage. Many clinicians have noticed that patients who had a history of low-grade chronic sinusitis before sinus elevation surgery were less susceptible to this condition after surgery. This is due to both the decreased volume of the sinus and the fact that the sinus floor is closer to the ostium. This assumes that proper membrane elevation up the medial wall has raised the floor without creating a narrow, difficult to drain crestal extension of the sinus floor against the medial wall. Follow-up evaluations of 24 sinus grafts found that 12 membranes decreased in size, 11 remained the same, and one increased in size (48).

Sinusitis after sinus elevation surgery, which has been reported in 3–20% of cases (5), is generally mild in nature. Symptoms may include mild discomfort, stuffiness, and difficulty in breathing. Moderate to severe postoperative sinusitis is most likely due to blockage of osteal drainage

owing to inflammation and/or sinus infection. The various etiologies include:

- postsurgical inflammatory changes
- bleeding into the sinus after membrane perforation
- bacterial contamination after membrane perforation
- blockage of the osteomeatal complex:
  - intrasinus bleeding
  - graft material lost through perforation
  - elevation of large cysts or thickened membranes to the level of the ostium.

Prevention

Prevention of postoperative sinusitis begins with an evaluation of the patient's history and final case selection. Patients with a previous history of inflammatory sinus disease are more likely to have a postoperative chronic sinusitis than patients with a negative history (49, 50). In either group, preoperative sinus pathology should be evaluated by CT analysis and potential problems dealt with before surgery. The proper presurgical protocol thus includes:

- 3D treatment planning to discover pre-existing pathology
- prior treatment of inflammatory disease by antibiotic and anti-inflammatory treatment or, if necessary, endoscopic surgery.

If perforation of the sinus membrane occurs during surgery, the repair must be made in a manner that is stable and prevents particulate graft material from escaping into the sinus cavity, as this may be a nidus for inflammatory changes, infection, or blockage of the ostium.

Treatment

Many clinicians routinely prescribe decongestants such as oxymetazoline (Afrin) for postoperative use. The postoperative incidence of cases requiring this therapy is so infrequent an occurrence that many clinicians do not include this in their usual postoperative protocol but prescribe it on an as-needed basis. Nasal lavage with sterile saline rinses can be used as adjunctive therapy.

Treatment will depend on the severity and presumptive etiology of the sinusitis. Mild sinusitis will respond to decongestants. If the etiology is a combination of inflammation and infection combined antibiotic and anti-inflammatory therapy can be effective. If the problem is due to blocked drainage, positive therapy might involve endoscopic marsupialization of an elevated mucous retention cyst, removal of polyps, or surgical widening of the ostium by an ENT specialist.

Other postoperative complications

Loss of graft material through the window

An increase in intrasinus pressure which may be caused by postoperative inflammation or bleeding from within the sinus can result in loss of graft material through the window (Fig. 16.43a, b). This is likely to occur if a mem-

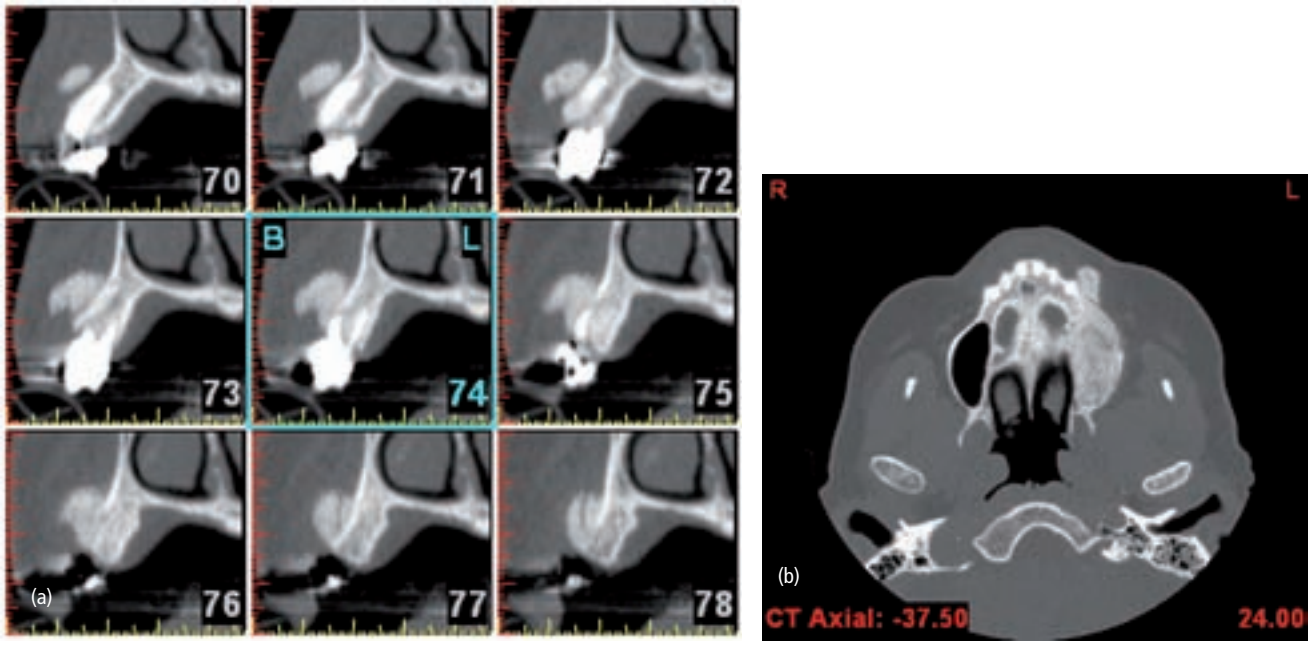


Fig. 16.43 (a) Displaced graft material following intrasinus bleeding (cross-sectional view). (b) Displaced graft material following intrasinus bleeding (axial CT view).

brane was not placed over the window or if the membrane was not stabilized. The displaced graft material is likely to cause an elevation in the buccal mucosa. This can be removed with a small flap entry (not over window or membrane) or left in place and addressed at the time of implant placement. Some clinicians stabilize bioabsorbable barrier membranes with resorbable tacks or a mattress suture. The incidence of this complication is so low that this may be considered unnecessary therapy.

Migration of implants into sinus or sinus graft

This complication was more common when cylinder implants were used in the posterior maxilla (51). It is still seen with screw-form implants when biologic boundaries are pushed to or beyond the limit (Fig. 16.44). The problem is usually due to an initially inadequate or early loss of primary stability. It can also be caused by the loss of supporting bone owing to infection. Most clinicians reserve simultaneous implant placement for those cases that have a minimum of 4–5 mm of crestal bone. While simultaneous placement has been reported to be successful in 1–2 mm of crestal bone (52), one must consider the risk. If an implant is placed in 1–3 mm of crestal bone and primary closure is not achieved, the early formation of the biologic width will remove more than half of the supporting bone well before the maturation of the graft.

Conclusion

The maxillary sinus elevation procedure using a lateral window approach has been shown to be the most successful bone augmentation procedure that is performed as a preprosthetic procedure before implant placement (1). When success is measured by patient outcome (success of the grafting procedure) the high success rate achieved is due to the fact that complications are minimal and can be reduced through proper case selection, good surgical technique, and proper and prompt handling of intraoperative and postoperative complications when they do occur. Properly performed sinus grafting does not alter proper sinus function (53) and does not alter the characteristics of the voice (54). When measured by implant outcome (implant survival rate) it has been shown that implant survival rates in the high 90th percentile can be achieved through proper decision making with regard to implant surfaces (textured), graft materials (highest survival with xenografts), and the placement of a barrier membrane over the window (1–3).

Each discussion of the prevention of an intraoperative or a postoperative complication included the advisability of obtaining a preoperative CT scan analysis. While this is not today considered part of the universal standard of care many clinicians feel that, based on the presurgical knowledge gained from these scans, it is highly advisable to obtain this diagnostic aid before performing a sinus augmentation procedure.

Take-home hints are listed following each section in this chapter.

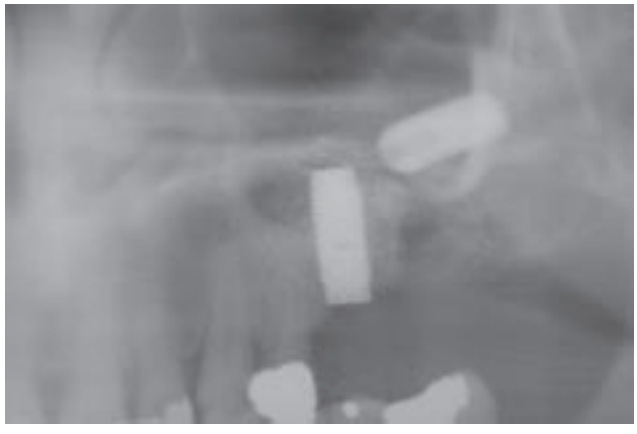


Fig. 16.44 Migration of the implant into the sinus cavity.

References

1. Aghaloo TL, Moy PK. Which hard tissue augmentation techniques are the most successful in furnishing bony support for implant placement? *Int J Oral Maxillofac Implants* 2007; **22** (Suppl): 49–70.
2. Wallace SS, Froum SJ. Effect of maxillary sinus augmentation on the survival of endosseous dental implants. A systematic review. *Ann Periodontol* 2003; **8**: 328–43.
3. Del Fabbro M, Testori T, Francetti L, Weinstein R. Systematic review of survival for implants placed in the grafted maxillary sinus. *Int J Periodontics Restorative Dent* 2004; **24**: 565–77.
4. Ziccardi VB, Betts NJ. Complications of maxillary sinus augmentation. In: Jensen OT, ed. *The sinus bone graft*. Chicago, IL: Quintessence, 1999: 201–8.
5. Misch CE. *Contemporary implant dentistry*, 3rd edn. St Louis, MO: Mosby, 2008: 905–74.
6. Pikos MA. In: Jensen OT, ed. *The sinus bone graft*, 2nd ed. Chicago, IL: Quintessence, 2006: 103–14.
7. Zijderveld SA, van den Bergh, JPA, Schulten EAJM, ten Bruggenkate CM. Anatomical and surgical findings and complications in 100 consecutive maxillary sinus floor elevations. *J Oral Maxillofac Surg* 2008; **66**: 1426–38.
8. Solar P, Geyerhofer U, Traxler H, Windish A, Ulm C, Watzak G. Blood supply to the maxillary sinus relevant to sinus floor elevation procedures. *Clin Oral Implants Res* 1999; **10**: 34–44.
9. Flanagan D. Arterial supply of maxillary sinus and potential for bleeding complication during lateral approach sinus elevation. *Implant Dent* 2005; **14**: 336–8.
10. Elian N, Wallace S, Cho SC, Jalbout ZN, Froum S. Distribution of the maxillary artery as it relates to sinus floor augmentation. *Int J Oral Maxillofac Implants* 2005; **20**: 784–7.

11. Mardinger O, Abba M. Hirshberg A, Schwartz-Arad D. Prevalence, diameter and course of the maxillary intraosseous vascular canal with relation to sinus augmentation procedure: a radiographic study. *Int J Oral Maxillofac Surg* 2007; **36**: 735–8.
12. Vercellotti T, De Paoli S, Nevins M. The piezoelectric bony window osteotomy and sinus membrane elevation: introduction of a new technique for simplification of the sinus augmentation procedure. *Int J Periodontics Restorative Dent* 2001; **21**: 561–7.
13. Beziat JL, Vercellotti T, Gleizal A. What is Piezosurgery? Two-years experience in craniomaxillofacial surgery. *Rev Stomatol Chir Maxillofac* 2007; **108**: 101–7.
14. Geha HJ, Gleizal AM, Beziat JL. Sensitivity of the inferior lip and chin following mandibular bilateral sagittal split osteotomy using Piezosurgery. *Plast Reconstr Surg* 2006; **118**: 598–607.
15. Schwartz-Arad D, Herzberg R, Dolev E. The prevalence of surgical complications of the sinus graft procedure and their impact on implant survival. *J Periodontol* 2004; **75**: 511–16.
16. Krekmanov L. A modified method of simultaneous bone grafting and placement of implants in the severely resorbed maxilla. *Int J Oral Maxillofac Implants* 1995; **10**: 682–8.
17. Kasabah S, Krug J, Simunek A, Lecaro MC. Can we predict maxillary sinus mucosa perforation? *Acta Med* 2003; **46**: 19–23.
18. Cho S-C, Wallace SS, Froum SJ, Tarnow DP. Influence of anatomy on Schneiderian membrane perforations during sinus elevation surgery: three-dimensional analysis. *Pract Proced Aesthet Dent* 2001; **13**: 160–3.
19. Velasquez-Plata D, Hovey L, Peach CC, Alder ME. Maxillary sinus septa: a 3-dimensional computerized tomographic scan analysis. *Int J Oral Maxillofac Implants* 2002; **17**: 854–60.
20. Betts MJ, Miloro M. Modification of the sinus lift procedure for septa in the maxillary antrum. *J Oral Maxillofac Surg* 1994; **52**: 332–3.
21. Wallace SS, Mazor Z, Froum SJ, Cho SC, Tarnow DP. Schneiderian membrane perforation rate during sinus elevation using Piezosurgery: clinical results of 100 consecutive cases. *Int J Periodontics Restorative Dent* 2007; **27**: 413–19.
22. Blus C, Szmukler-Moncler S, Salama M, Salama H, Garber D. Sinus bone grafting procedures using ultrasonic bone surgery: 5-year experience. *Int J Periodontics Restorative Dent* 2008; **28**: 221–9.
23. Toscano NJ, Holtzclaw D, Rosen PS. The effect of piezoelectric use on open sinus lift perforation: A retrospective evaluation of 56 consecutively treated cases from private practices. *J Periodontol* 2010; **81**: 167–71.
24. Barone A, Santini S, Marconcini S, Giacomelli L, Gherlone E, Covani U. Osteotomy and membrane elevation during the maxillary sinus augmentation procedure. A comparative study: piezoelectric device vs. conventional rotary instruments. *Clin Oral Implants Res* 2008; **19**: 511–15.
25. Triplett RG, Schow SR. Autologous bone grafts and endosseous implants: complementary techniques. *J Oral Maxillofac Surg* 1996; **54**: 486–94.
26. Keller EE, Eckert SE, Tolman DE. Maxillary antral and nasal one-stage inlay composite bone graft. Preliminary report on 30 recipient sites. *J Oral Maxillofac Surg* 1994; **52**: 438–47.
27. Proussaefs P, Lozada J, Kim J, Rohrer MD. Repair of the perforated sinus membrane with a resorbable collagen membrane: a human study. *Int J Oral Maxillofac Implants* 2004; **19**: 413–20.
28. Pikos MA. Maxillary sinus membrane repair: report of a technique for large perforations. *Implant Dent* 1999; **8**: 29–33.
29. Vlassis JM, Fugazzotto PA. A classification system for sinus membrane perforations during augmentation procedures with options for repair. *J Periodontol* 1999; **70**: 692–9.
30. Fugazzotto PA, Vlassis JM. A simplified classification and repair system for sinus membrane perforations. *J Periodontol* 2003; **74**: 1534–41.
31. Proussaefs A, Lozada J. The "Loma Linda pouch": a technique for repairing the perforated sinus membrane. *Int J Periodontics Restorative Dent* 2003; **23**: 593–7.
32. Wallace SS, Froum SJ, Tarnow DP. In: Jensen OT, ed. *The sinus bone graft*, 2nd ed. Chicago, IL: Quintessence, 2006: 229–39.
33. Testori T, Wallace SS, Del Fabbro M, Taschieri S, Trisi P, Capelli M, Weinstein RL. Repair of large sinus membrane perforations using stabilized collagen barrier membranes: surgical techniques with histologic, and radiographic evidence of success. *Int J Periodontics Restorative Dent* 2008; **28**: 9–17.
34. Shlomi B, Horowitz I, Kahn A, Dodriyan A, Chaushu G. The effect of sinus membrane perforation and repair with Lambone sheet on the outcome of maxillary sinus floor augmentation: a radiographic assessment. *Int J Oral Maxillofac Implants* 2004; **19**: 559–62.
35. Hürzeler MB, Quiñones CR, Kirsch A, Gloker C, Schüpbach P, Strub JR. Maxillary sinus augmentation using different grafting materials and dental implants in monkeys. Part 1. Evaluation of anorganic bovine bone-derived bone matrix. *Clin Oral Implants Res* 1997; **8**: 476–86.
36. Haas R, Baron M, Donath K, Zechner W, Watzek G. Porous hydroxyapatite for grafting the maxillary sinus. *Int J Oral Maxillofac Implants* 2002; **17**: 337–46.
37. Jensen OT, Shulman LB, Block MS, Iacono VJ. Report of the Sinus Consensus Conference of 1996. *Int J Oral Maxillofac Implants* 1998; **13** (Suppl): 11–45.
38. Khoury F. Augmentation of the sinus floor with mandibular bone block and simultaneous implantation. *Int J Oral Maxillofac Implants* 1999; **14**: 557–64.
39. Hernández-Alfaro F, Torradeflot MM, Marti C. Prevalence and management of Schneiderian membrane perforations during sinus-lift procedures. *Clin Oral Implants Res* 2008; **19**: 91–8.
40. Ardekian L, Oved-Peleg E, Mactei EE, Peled M. The clinical significance of sinus membrane perforation during augmentation of the maxillary sinus. *J Oral Maxillofac Surg* 2006; **64**: 277–82.
41. Karabuda C, Arisan V, Hakan O. Effects of sinus membrane perforation on the success of dental implants placed in the augmented sinus. *J Periodontol* 2006; **77**: 991–7.
42. Misch CM, Misch CE, Resnik RR, Ismael YH, Appel B. Postoperative maxillary cyst associated with a maxillary sinus

elevation procedure: a case report. *J Oral Implantol* 1991; **17**: 432–7.
43. Lockhart R, Ceccaidi J, Bertrand JC. Postoperative maxillary cyst following sinus bone graft: report of a case. *Int J Oral Maxillofac Implants* 2000; **15**: 583–6.
44. Barone A, Santini S, Sbordone L, Crespi R, Covani U. A clinical study of the outcomes and complications associated with maxillary sinus augmentation. *Int J Oral Maxillofac Implants* 2006; **21**: 81–5.
45. Levin L, Herzberg R, Dolev E, Schwartz-Arad D. Smoking and complications of onlay bone grafts and sinus lift operations. *Int J Oral Maxillofac Implants* 2004; **19**: 369–73.
46. Parmar C, Meda KP. Achilles tendon rupture associated with combination therapy of levofloxacin and steroid in four patients and a review of the literature. *Foot Ankle Int* 2007; **28**: 1287–9.
47. Wagenberg B, Froum SJ. A retrospective of 1925 consecutively placed implants from 1988–2004. *J Oral Maxillofac Implants* 2006; **21**: 565–78.
48. Peleg M, Chaushu G, Mazur Z, Ardekian L, Bakoon M. Radiological findings of the post-sinus lift maxillary sinus: a computerized tomography follow-up. *J Periodontol* 1999; **70**: 1564–73.
49. Timmenga NM, Raghoebar GM, Boering G, van Weissenbruch R. Maxillary sinus function after sinus lifts for the insertion of dental implants. *J Oral Maxillofac Surg* 1997: **55**: 936–9.
50. Timmenga NM, Raghoebar GM, van Weissenbruch R, Vissink A. Maxillary sinus floor elevation surgery. A clinical, radiographic and endoscopic evaluation. *Clin Oral Implants Res* 2003; **14**: 322–8.
51. Regev E, Smith RA, Perrott DH, Pogrel MA. Maxillary sinus complications related to endosseous implants. *Int J Oral Maxillofac Implants* 1995; **10**: 451–61.
52. Peleg M, Garg AK, Mazur Z. Predictability of simultaneous implant placement in the severely atrophic posterior maxilla: a 9-year longitudinal experience study of 2132 implants placed into 731 human sinus grafts. *Int J Oral Maxillofac Implants* 2006; **21**: 94–102.
53. Timmenga NM, Raghoebar GM, Liem RS, van Weissenbruch R, Manson WL, Vissink A. Effects of maxillary sinus floor elevation surgery on maxillary sinus physiology. *Eur J Oral Sci* 203; **111**: 189–97.
54. Tepper G, Haas R, Schneider B, Watzak G, Maitath G, Jovanovic SA, *et al.* Effects of sinus lifting on voice quality. A prospective study and risk assessment. *Clin Oral Implants Res* 2003; **14**: 767–74.

Chapter 17

Complications with the bone-added osteotome sinus floor elevation: etiology, prevention, and treatment

Paul S. Rosen DMD, MS

Incidence

Treatment of the posterior edentulous maxilla can be complicated by atrophy of the edentulous ridge or by an aging-related increase in the pneumatization of the maxillary sinus. The technique of sinus floor elevation has expanded the prosthetic rehabilitation options for this region through the placement of dental implants.

Traditionally, a lateral wall (Caldwell-Luc) approach to sinus augmentation has been used owing to both its versatility and high predictability for creating new bone in this area. Numerous studies and meta-analyses (1–3) have confirmed the clinical observations of implant successes with this lateral window approach. However, this technique can be quite aggressive and often patients would prefer an option that stresses minimalism. A less invasive alternative to the lateral window approach for sinus elevation was introduced by Summers in 1994 (4). This technique, known as bone-added osteotome sinus floor elevation (BAOSFE), proposed that a bone replacement graft be used simultaneous to the placement of the dental implant. The BAOSFE procedure attempts to augment the existing crestal bone under the sinus with graft materials, elevating the sinus floor and increasing osseous support for an implant. The combined mass of the native bone with the bone replacement graft material acts like a hydraulic plug to elevate the sinus floor. Implants are placed after the tenting of the sinus membrane with their apical end further facilitating the elevation of the sinus membrane. Implant stability initially relies on the host bone present at the created osteotomy site, while future additional support is potentially gained by the consolidation and amalgamation of the grafted material with newly formed host bone. Several case series reports (5–9) attest to the success of this procedure, furthering its popularity among clinicians. More recently, in a pilot study, Nedir *et al.* (10) demonstrated that a success rate of better than 90% can be achieved with this procedure in sinuses where preoperative bone height averaged approximately 5.5 mm (range 6–9 mm) without the use of a bone replacement graft. This confirmed the successes of others who have modified the internal sinus lift technique, performing the elevation without concurrent use of a bone replacement graft (11, 12).

Similarly to any other procedure, BAOSFE has received innovative modifications (13) in an effort to achieve greater simplicity or greater success with reduced complications. Some of these modifications have included using medical devices and instruments that are specific to their particular technique (14). Although these techniques have all demonstrated high rates of success, insufficient evidence exists in the form of prospective studies to validate their inclusion in this chapter. Therefore, techniques such as localized management of the sinus floor (11, 12), hydraulic sinus lift (15), minimally invasive antral membrane balloon elevation (MIAMBE) (16, 17), and several others are not included in this chapter.

The difficulty in ascertaining the incidence of complications associated with any procedure or technique from controlled clinical trials or even case reports is the inherent publishing bias (positive results are published more frequently than negative results). Furthermore, clinicians are reticent, in open forum, to share their suboptimal experiences. This is indeed true with BAOSFE. Much of the information that is brought forward in this chapter has been gained through the literature, particularly when authors have reported on complications or failures with BAOSFE, personal experiences, and second-hand information, e.g. conversations with fellow colleagues or lectures attended. To all those who have been kind enough to provide their personal insight, the author and the readers of this chapter owe a debt of gratitude.

Determining the incidence of complications, one must first look at implant failures with BAOSFE. However, most studies and case reports have focussed on successful outcomes. When evaluating the body of literature regarding BAOSFE, meta-analysis is the most dispassionate and extensive way to gain this clinically valuable information. In 2005, Emmerich *et al.* (18) published the first meta-analysis report that strictly reviewed the use of

osteotomes for sinus floor elevation. Their analysis revealed over 44 articles for evaluation, of which eight (11, 19–25) met their rigorous inclusion criteria. All of these studies did not include criteria for success, so survival rate was calculated with a minimum of 6 months of loading. In total, 1139 implants were appropriate for meta-analysis and the percentage of implants lost was 1.8%, 2.5%, 4.3%, and 9.1%, after 6, 12, 24, and 36 months, respectively. Table 17.1, which appeared in the Emmerich (18) article, enumerates some of the complicating factors that may have caused the implants to fail. Recurring etiologies of implant failure listed in their table include lack of primary stability, type IV bone quality, and occlusal traumatic forces from either a partial denture or parafunction. The most consistent fact about implant failures associated with BAOSFE is that they usually occur before loading.

A second meta-analysis on osteotome use was published by Shalabi *et al.* (26). These authors estimated the 4.5-year survival rate of implants that were placed using the osteotome technique. Their inclusion criteria were different from the former meta-analysis (18). Shalabi *et al.* (26), in their literature search, revealed five studies (4, 23, 25–29) for inclusion of the 164 that were reviewed. The combined data of 349 implants revealed a failure probability of 2% before loading and 1% after 56 months of loading. At the end of the observation period, 41 implants in 18 patients were still at risk.

One additional prospective study, by Ferrigno *et al.* (31), was published since the time of these two meta-analyses and should also be mentioned. The 12-year cumulative loss rate based on their calculation of implant survival was 5.2%, which is slightly better than Emmerich (18), but well within the grouping of all of the included studies.

A third meta-analysis was published in 2008 by Tan *et al.* (32) on transalveolar sinus elevation, which they termed an osteotome technique. This exhaustive literature search identified 19 studies which met the authors' inclusion criteria, of which ten studies (6, 9, 10, 12, 22, 30, 32–35) reported on complications. The authors noted that these ten articles included a total of 1776 implants and the most commonly reported complication was sinus perforation. Only eight of these ten studies (6, 9, 10, 30, 32–35) reported on this. There was a total of 1621 implants from these studies with 61 membrane perforations noted, for an overall rate of 3.8% (range 0–21.4%). The most common postoperative complication was infection; only six of the studies (9, 12, 22, 32, 34, 35) reported on this. There was a total of 884 implants from these studies of which seven had infections, a rate of 0.8% (range 0–2.5%). Other complications found in this meta-analysis included postoperative hemorrhage, nasal bleeding, blocked nose, hematomas, and cover screw loosening that resulted in suppuration.

Etiology

Infection

First and foremost among the list of etiologies for possible complications is infection. Site infection may be related to poor oral hygiene, contamination of the implant surface at the time of insertion, or graft material contamination, or may be due to the sinus having underlying disease, particularly if a sinus membrane perforation were to occur during elevation of the sinus. Such events could lead to failure of the implant owing to a lack of osseointegration or the development of peri-implantitis.

Inadequate primary stability related to pretreatment bone height/width

Implant success and survival with BAOSFE rely on good primary stability of the implant at the time of placement. There can be several reasons why the implant is not well stabilized. Having enough vertical bone height, before placement with the BAOSFE procedure, appears to impact stability and implant success (9, 19) (Fig. 17.1a–f). Rosen *et al.* (19) and Toffler (9) provided case series data that demonstrated an almost 10–20% increase in failures when the subantral bone measured 4 mm or less at the time of implant placement. A narrower ridge width with diminished bone height below the sinus may also have a negative impact on success since tapping the osteotomes in denser bone may cause the site to become overprepared, causing the implant to be placed without adequate primary stability.

Inadequate primary stability related to bone quality

Historically, implant failures have increased particularly when bone has been of type IV quality (36). Some clinicians feel that the use of osteotomes may condense the bone, thereby modifying type IV bone to type II or type III (37). This compression of the bed may increase the bone-to-implant contact and allow for better stability and integration.

Inadequate primary stability related to premature loading of the implant

Several studies have discussed that the wearing of a removable partial denture may have caused premature loading of BAOSFE-placed implants leading to their failure to integrate (11, 22). The option of avoiding the use of a removable partial denture, if practical, would be ideal. However, this is usually not the case. Therefore, the clinician has to design and adjust the patient's interim

Table 17.1 Information about clinical locations, patient condition, implant and augmentation material, causes of implant failure, preoperative bone height, and bone gain

Ref.	Clinical location	Patient condition	Implant and augmentation material	Cause of failure	Preoperative bone height (mm)		Radiograph bone gain (mm)
					Recommended	Measured	
Bruschi *et al.* (11)	Private practice, Rome, Italy	No sinusitis; no periodontitis	Cylinders, rough surface[a] ($n = 317$); stepped cylinders and/or screws, rough-surface[b] ($n = 182$) Collagen sheet	12 clustered failures: 3 failures in one patient with removable partial denture and clasps to teeth	5–7	N/A	N/A
Cavicchia *et al.* (22)	Private practice, Rome, Italy	None	Cylinders, rough surface[a,c] ($n = 25$); stepped screws, rough-surface[b] ($n = 72$); length usually 10 mm, six 8 mm Collagen sponge, autogenous bone	11 failures: 8 due to lack of primary stability (all type IV bone, 3 with removable denture, 6 with local bone < 50% of final implant length); 2 after almost 9 months; 1 after 4 years (8 mm implant type IV bone, heavy smoker)	5–7	N/A	1–6 (mean 2.9)
Coatoam & Krieger (20)	Private practice and Faculty of Periodontics, University of Florida, USA	None	Turned screws[d] ($n = 2$); cylinders, rough surface[e] ($n = 13$); cylinders, rough surface[f] ($n = 5$); flared cylinders, rough surface[g] ($n = 69$) Demineralized freeze-dried bone allograft and autogenous bone[m,n]	7 failures: 5 due to lack of primary stability; 1 by occlusal trauma; 1 implant migrated into maxillary sinus	≥5	N/A	N/A
Deporter *et al.* (21)	Faculty of Dentistry, University of Toronto, Canada	No history of sinusitis; no periodontitis; no smokers	Tapered press fit implants, rough surface[h]; mean length 6.9 mm Anorganic bovine bone mineral[m]	No failures	≥3	N/A	N/A
Fugazzotto & De Paoli *et al.* (23)	Private practice, Milton, MA, USA	No sinusitis; no periodonitis; <20 cigarettes	Self-tapping screws [c]; screws, rough surface[i]; length 8–11.5 mm Anorganic bovine bone mineral[m]	3 failures: 2 failed to integrate; 1 after 8 months due to parafunction	N/A	N/A	N/A
Fugazzotto (24)	Private practice, Milton, MA, USA	No sinusitis; no periodontitis; <20 cigarettes	Self-tapping screws[c] ($n = 7$); screws, rough surface[k] ($n = 109$); length 7–11 mm, no correlation to failure No bone substitute added	2 failures: Implants mobile at abutment connection	4–5	N/A	N/A
Rosen *et al.* (19)	Multicenter study dental schools and private practices, USA	No immune disease, uncontrolled diabetes, chemotherapy, radiation, alcohol/drug abuse, or psychologic instability	Standard screws[c,j,k,l]; cylinders, rough surface[a,c]; screws, rough surface[j] Autogenous bone, demineralized freeze-dried bone allograft, freeze-dried bone allograft, anorganic bovine bone minerals[m,n]	8 failures: 3 before loading; 3 between 6 and 12 months' loading; 2 after >1 year of loading 93%/96% survival rate in smokers/non-smokers All implant types: survival rate >93% Initial bone height ≥4 mm 85.7%; >4 mm 96%; 6 mm implants 80%	≥3	≥ 3	N/A
Zitzmann & Schaerer (25)	Department of Fixed and Removable Prosthodontics, Universities at Basel/ Zürich, Switzerland	No sinus pathology	Turned screws[l]; length usually ≥10 mm, 8.5 mm acceptable if splinted Anorganic bovine bone mineral[m]	3 failures: 2 mobile at abutment connection; 1 mobile 4 weeks after abutment connection	≥6	Mean 8.8	Mean 3.5

Modified from Emmerich *et al.* (18), with permission from the Managing Editor, *Journal of Periodontology*.
Implants: [a] IMZ, Dentsply, York, PA, USA; [b] Frialit 2 implants, Dentsply; [c] 3i, West Palm Beach, FL, USA; [d] Screw Vent, Paragon Implant Co. Sulzer Medica, Enicno, CA, USA; [e] Bio-Vent, Paragon Implant Co. Sulzer Medica; [f] Steri-Oss, Nobel Biocare, Göteborg, Sweden; [g] PACE implants, CAL-Form, Longwood, FL, USA; [h] Endopore, Innova LifeScience Corp., Toronto, ON, Canada; [i] ITI Straumann AG, Waldenburg, Switzerland; [j] not specified; Dentsply standard screws, Dentsply; [k] not specified; Implamed standard screws, Impla-Med, Sunrise, FL, USA; [l] Brånemark implants, Nobel Biocare.
Augmentation material: [m] Bio-Oss, OsteoHealth Co., Shirley, NY, USA; [n] Osteograf-N, Dentsply/CeraMed, Lakewood, CO, USA.
N/A: not applicable.

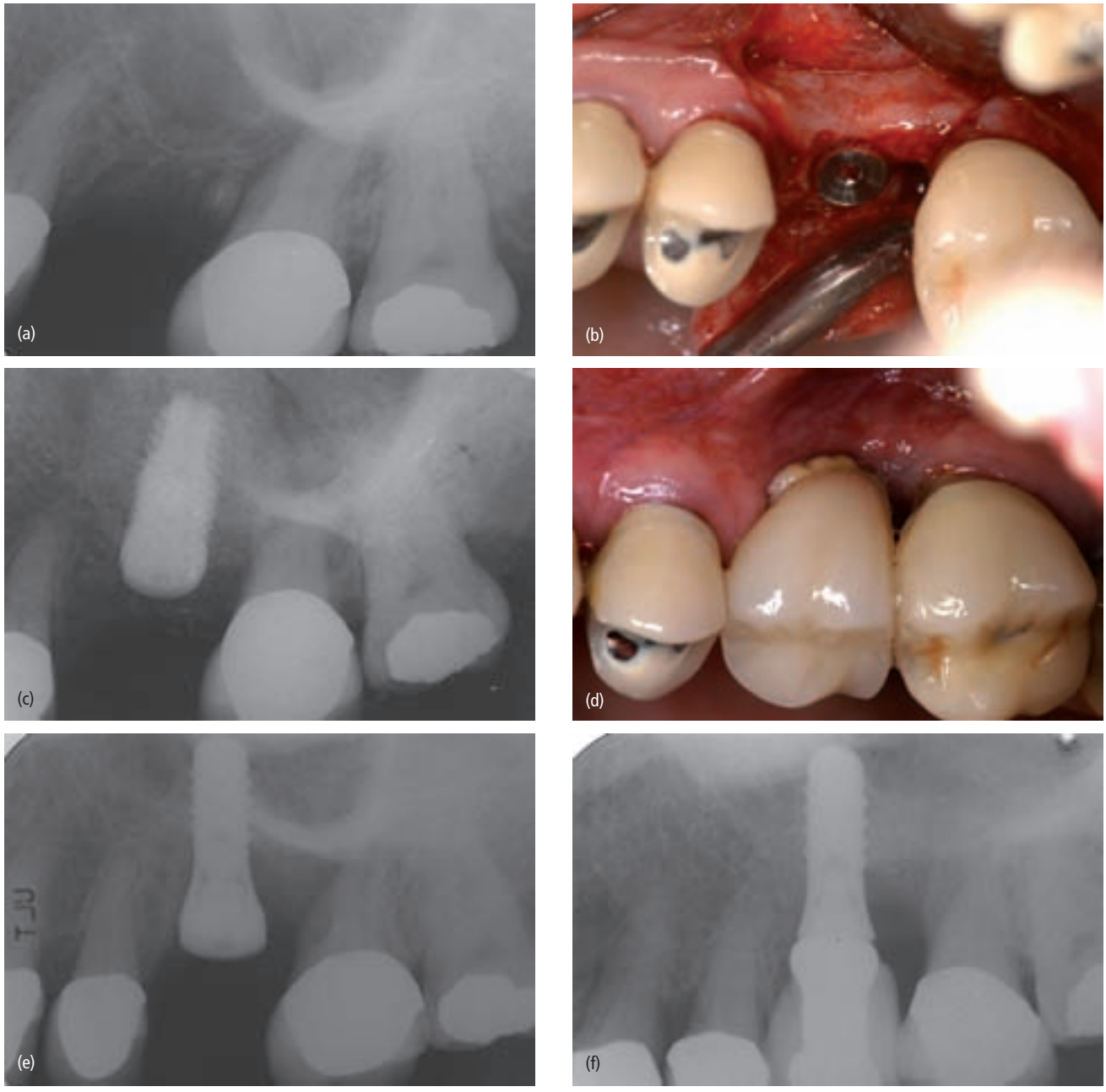


Fig. 17.1 (a) Presurgical radiograph of the sinus area before treatment. Presurgical measurement is less than 5 mm of native bone. The residual root tip located mesial to the second molar was removed at the time of implant placement. (b) Clinical view of the implant placement at the site of the maxillary left first molar simultaneous to osteotome sinus floor elevation. The implant was submerged and allowed to heal for 6 months. (c) Radiograph showing a 10 mm implant placed in conjunction with the use of mineralized freeze-dried bone augmentation of the sinus area. The graft material appears to be contained. (d) Clinical view of the crown installed on the implant. The implant failed within weeks of its restoration. (e) Radiographic taken after placing the second implant at this failed site. The implant was placed with the abutment exposed. (f) Radiographic view of the second implant restored and in function for 3 years.

prosthesis to ensure that there are no forces placed on the implant(s) at any time.

Inadequate primary stability related to site preparation

Overpreparation of the site with BAOSFE is a concern when creating the osteotomy with the mallets. Büchter and colleagues (38) demonstrated, in an *ex vivo* model, significantly higher removal torque values for implants placed with a conventional technique compared to those with the osteotome. This finding of diminished primary stability has been further corroborated *in vivo* where at 28 days removal torque again was higher for conventional versus osteotome implant placement (39, 40). Underpreparation can also be of concern. If the site were

to be underprepared, irreversible damage might occur from excessive compression during implant placement with fracture of the bony trabeculae and poor recovery of vital bone.

Without adequate stability of the implant, there is a potential risk for migration of the implant into the sinus. This concern is mentioned in the Emmerich review (18) (Table 17.1), citing the study of Coatoam and Krieger (20). Explanations for migration of an implant into the sinus beyond the issue of stability have been offered. These include bone weakness in the posterior maxilla owing to the diminished scant thickness and density in this region, osteopenia or osteoporosis predisposing the patient to poor bone quality, and/or surgical technique that overprepares the site leading to a poorly stabilized implant. Delayed migration of an implant into the sinus is more poorly understood. Some of the mechanisms proposed for this include changes in intranasal and nasal pressure, autoimmune reaction to the implant, causing peri-implant bone destruction and compromising osseointegration, and resorption produced by incorrect distribution of occlusal forces (41, 42).

Sinus membrane tears related to excessive tapping, anatomy, or overzealous elevation

The complication of a sinus membrane tear is more common than one might believe (Figs 17.2, 17.3). Signs of membrane tear can be the development of sinusitis, epistaxis, or exfoliation of graft particles from the nose. Development of a sinus tear during BAOSFE is not always apparent and sometimes must be determined by the valsalva maneuver or more accurately by inspection with an endoscope (14).

There can be many reasons for the occurrence of membrane perforations. Depending on which article is cited, the incidence of membrane perforations ranges from 4 to 25% of osteotome cases (6, 9, 10, 30, 32–35, 43). In reality, microscopic tears are, in many instances, impossible to diagnose and therefore their incidence is often underestimated. Causes for tearing of the membrane can be related to inserting the osteotome beyond the sinus border, which Summers (4) cautioned against in his original article. This unfortunate occurrence can be related to difficulty in initial infracturing of the sinus floor. One possible cause for this could be angulation of the sinus floor at the site of preparation leading to dissimilar heights in the area where the osteotome encounters the inferior sinus wall. Figure 17.4 illustrates a likely ideal sinus to treat with BAOSFE, while Fig. 17.5 shows a sinus wall where it would be more difficult to create an infracture.

Reiser *et al.* (43) identified that sinus anatomy may be related to membrane tears. These authors looked at the membrane response to osteotome use in human cadavers. Of the 25 sites that were implanted, six showed perforations, a rate of 24%. Of these six, four of the perforations were associated with proximity of the osteo-

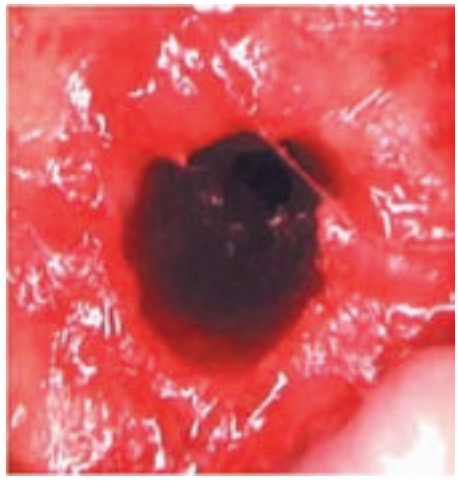


Fig. 17.2 Implant site preparation using osteotomes. There is a class I perforation of the sinus membrane. (Courtesy of Michael Toffler.)

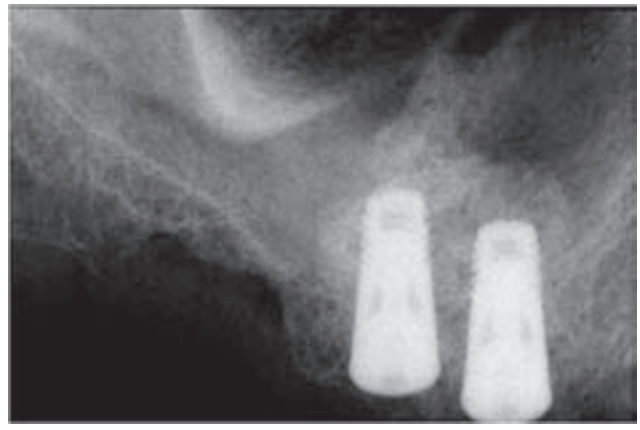


Fig. 17.3 Periapical radiograph suggesting a sinus tear at the maxillary right first molar. The bone graft material is poorly contained, as indicated by the lack of a dome shape to the sinus lift. (Courtesy of Michael Toffler.)

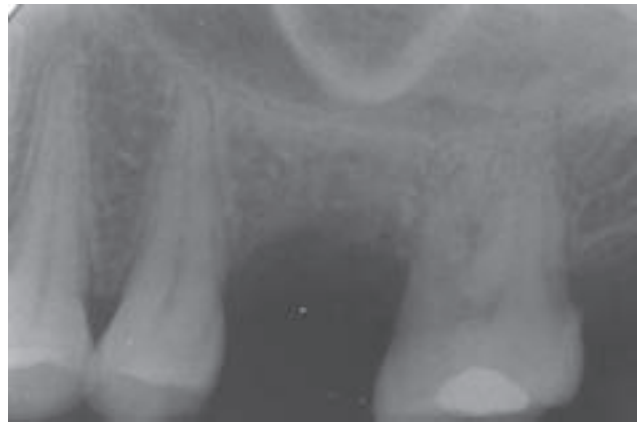


Fig. 17.4 Periapical radiograph suggesting that the sinus wall is flat in its profile. This sinus is more amenable to infracture with the osteotome technique.

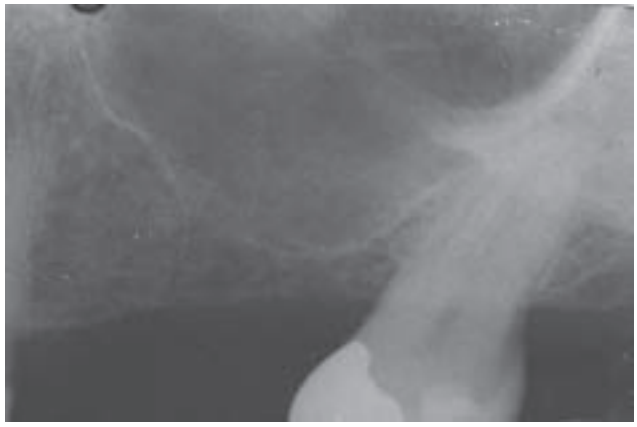


Fig. 17.5 Periapical radiograph suggesting that there is a slope to the sinus wall at the maxillary left second premolar site which could complicate the use of osteotomes to create the infracture of the wall.

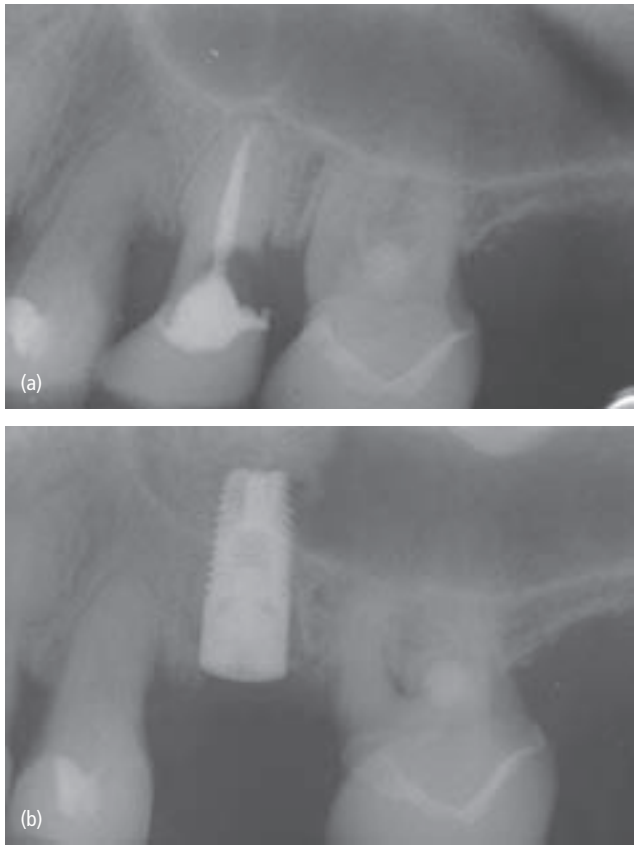
tomy to antral septae (Fig. 17.6a–c) or the collateral wall of the nose. To avoid this complication, it is therefore important to identify antral septae before proceeding.

Trying to elevate the Schneiderian membrane beyond its capacity to adapt can also cause the sinus membrane to tear. Pommer *et al.* (44) reported from a human cadaver study that there was a limit to how far the sinus membrane could be stretched and that thicker membranes demonstrated significantly higher load limits. The clinician is constantly challenged in determining what is a reasonable elevation of the membrane since a wide variation has been reported. Komarnyckyj and London (27) reported a range of 3–9 mm (average 5.4 mm), while Baumann and Ewers (45) reported that 13 mm of elevation was achieved in one case. These disparate differences make it difficult to determine what a reasonable goal is for a given individual who is to undergo osteotome sinus floor elevation.

Other possible causes for membrane tears may include the sharp nature of some of the particulate graft materials placed into the osteotomy or too rapid elevation of the membrane.

Reiser *et al.* (43) classified the sinus tears as either class I (≤ 2 mm with exposure of the implant into the sinus cavity and loss of doming) or class II perforations (≥ 2 mm). The authors believed that in the case of the class I perforations, the remaining graft and blood clot would serve as a vital scaffold allowing spontaneous healing of the membrane, while with class II perforations (12% of the sites) implant failure would be inevitable. Figure 17.7(a–i) demonstrates some the case examples from Reiser *et al.* (43).

Another concern with sinus membrane perforation is the potential for the tear to lead to a patent oral–antral communication. This would be more common in a patient with underlying sinus disease, which could diminish the possibility for healing of a sinus membrane tear.



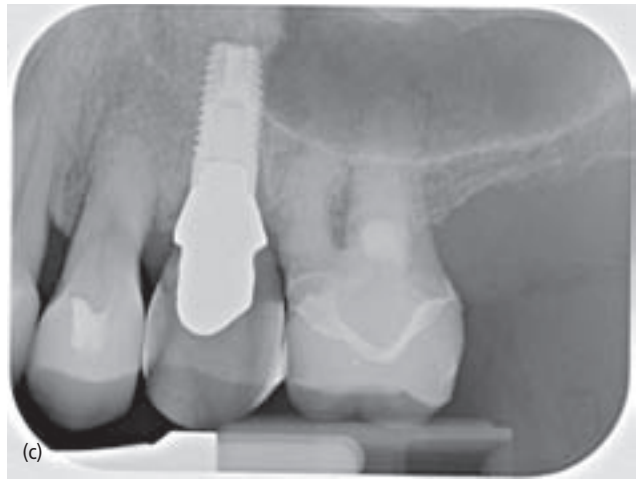


Fig. 17.6 (a) Periapical radiograph suggesting a septum in the sinus at the area of the maxillary left second premolar. (b) Osteotome sinus elevation in the area of the second premolar. Sinus elevation was accomplished at the mesial aspect but not at the distal aspect, which was limited by the anatomic septum present. (c) Final crown in place showing stability to the grafted sinus and implant. (Prosthetic care was performed by David Faust, DMD, Yardley, Pennsylvania, USA.)

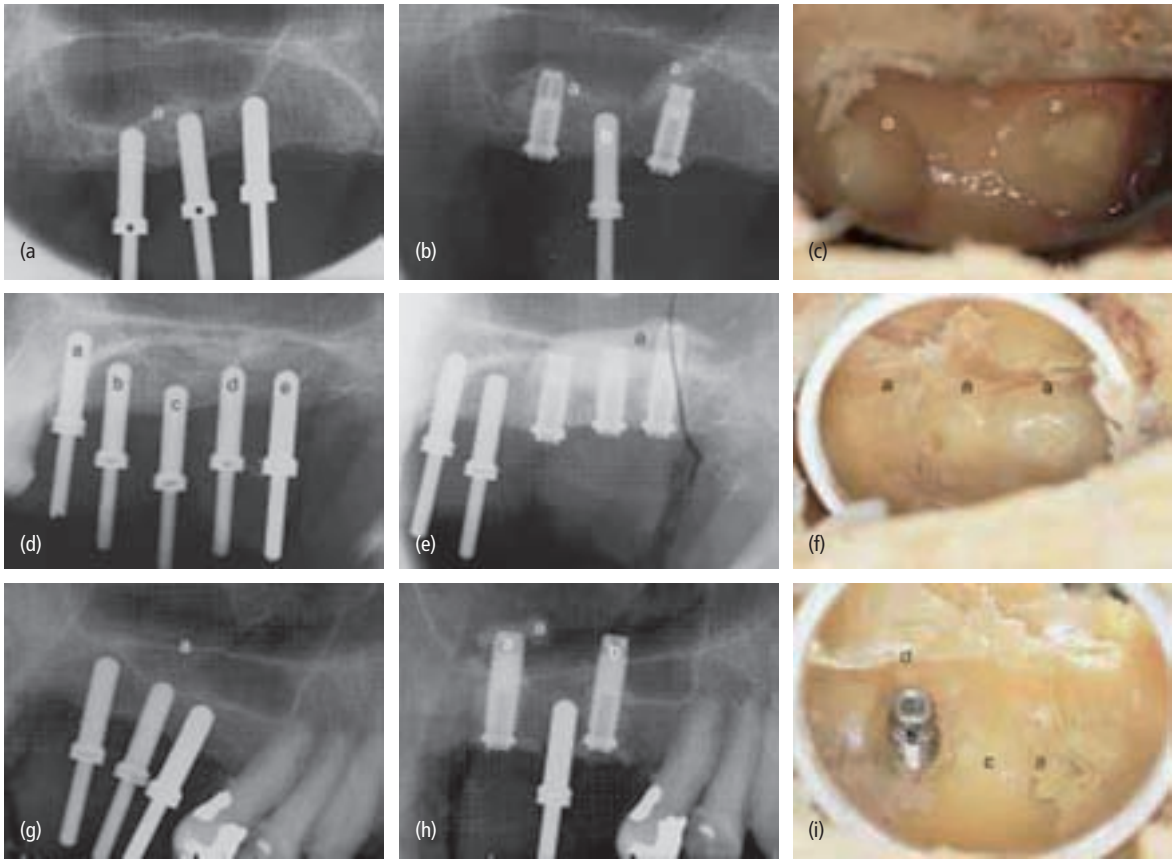


Fig. 17.7 (a) Three radiopaque indicators in place within 1 mm of the sinus floor *a*. (b) Implant placement following osteotome technique provided so as to elevate the maxillary sinus membrane. Notice the radiopaque material surrounding the implants *a* in comparison to the control site *b*. (c) Dome-shaped elevation of the maxillary sinus membrane demonstrated by intrasinus photography achieved by careful dissection of the lateral wall of the nose and placement of an intraoral mirror at the middle third of the sinus. No perforation was present. Notice the moist sinus. Intact dome-shaped elevations *a* are clearly demonstrated. (d–f) Multiple implant placement with the osteotome technique. (d) Radiographic presentation of orientation drill *a*, control site *b*, and test sites *c*–*e*. (e) The same region after sinus elevation and implant placement. Notice that the radiopaque material around the implants is contained with no indication of perforation *a*. (f) Continuous doming of the maxillary sinus membrane *a*. This documentation demonstrates that contiguous doming can be successfully achieved using the crestal osteotome technique. (g) Three radiopaque indicators in place; the middle serving as a control. Notice the nasal floor *a*. (h) Implants in place. Notice the partial loss of containment of the radiopaque material around the distal implant *a* and the lack of radiopaque material around the mesial implant *b*. (i) Demonstration of a class I perforation *a*, and a class II perforation *b*, adjacent to an incomplete septum *c*, located at the floor of the sinus. Proximity to the collateral nasal wall *d* can also be noted. Class I perforation is shown around the distal implant *a*. The dome-shaped elevation is still maintained by the implant. It is possible, in a clinical situation, for the remaining graft and blood clot to serve as a vital scaffold, allowing spontaneous healing of the membrane. The prognosis for such an implant *in vivo* is considered favorable. Class II perforation is shown around the mesial implant *b*. Loss of the dome-shaped elevation and implant protrusion to the sinus space are noted. The prognosis for such an implant *in vivo* is considered guarded. (Reproduced with permission from Reiser *et al.* (43). © Quintessence Publishing Co.)

Osteotome malleting leading to benign paroxysmal positional vertigo or poor patient experience

Incidents of significant headache, labyrinthitis and, more recently, benign paroxysmal positional vertigo (BPPV) have been reported following the use of the osteotome for both internal sinus floor elevation (46, 47) and ridge widening (48, 49). Symptoms of BPPV include dizziness or vertigo, imbalance, lightheadedness, and nausea. These symptoms are almost always caused by a change in the position of the head with respect to gravity. BPPV is not progressive, will occur suddenly and unpredictably, and can be temporarily incapacitating. Di Girolamo *et al.* (47) postulated that the surgical trauma, particularly the pressure exerted by the osteotomes, may cause the detachment of the otoliths known as otoconia from the utricular macula. These calcium carbonate crystals, while floating in the inner ear fluid, could strike against sensitive nerve endings within the balance apparatus at the end of each semicircular canal, creating the position- or motion-induced vertigo. The patient's head position, hyperextended and tilted opposite to the side from where the operator is working, favors the entry of these free-floating particles into the posterior semicircular canal of the implanted side. While in the majority of cases of BPPV the etiology is unknown, it may follow viral infection, vascular disorders, and head trauma. It is

believed that BPPV may account for 50% of all dizziness in older individuals (50). BPPV is self-limiting and symptoms subside or disappear within 6 months of onset.

Poor patient experience related to the malleting involved with the osteotome is the greatest single complaint of this procedure. Diserens and colleagues (51) compared the responses of 55 patients who had undergone sinus elevation with the Summers osteotome technique (4) to a group of patients who received implants in the same location during the same period using standard implant placement. A visual analogue score was used to help gauge patient responses. The groups did not differ in their perception of pain; however, the osteotome group judged the procedure more negatively. The biggest concern centered around the tapping, during which some patients expressed that they had experienced strong sensations and discomfort. However, pain itself was not the primary complaint.

Prevention

The best way to manage complications is to avoid them rather than treat them. The cost in time, effort, and aggravation to treat complications can be prohibitive. This section on prevention is divided along the topics of the etiology section: infection, primary stability, premature loading, overpreparation of the site, membrane tears, and BPPV and poor patient experience. It is impossible to provide a solely evidence-based approach to complication avoidance since the subjects of prevention and management of complications are very dynamic and will continue to evolve as more information comes to light. The information that follows, however, is based on the literature, the author's experience, and conversations with other clinicians. Over time the recommendations that are offered may change as new information comes to light and as newer techniques are studied and adopted.

Infection

When performing BAOSFE strong consideration should be given to minimizing the bacterial load at the time of the surgery. Any active periodontal disease or endodontic infection, particularly in the area of the procedure, should be addressed before proceeding. The use of presurgical antiseptic rinses and systemic administration of antibiotics will further decrease potential pathogenic bacteria. The same consideration might be given to using postsurgical antibiotics and an antiseptic mouthrinse to reduce the complication of postoperative infection. Every clinician must weigh the risks and benefits of using antibiotics during the perioperative and postoperative period to reduce or eliminate infection as a complication and/or an inevitable cause for implant or procedure failure before making treatment decisions.

Primary stability

Good primary stability for the implant can be achieved when elevating the sinus floor with osteotomes. Consideration might be given to selecting a tapered implant for use versus one with a straight-wall design. The taper of the implant will give some added stability related to the wedging that occurs when inserting this particular design (Fig. 17.8a, b). A rough-surfaced implant is recommended since it will aid in gaining optimal primary stability (52).

Several authors (4, 9, 19) have emphasized the need for at least 5 mm of vertical bone height beneath the sinus wall at the site before surgery to ensure a higher chance of success. The success rate when there is a pretreatment bone height of less than 5 mm beneath the sinus is in the mid-80% range. This figure is diminished by approximately 10% when there is less than 5 mm of native crestal height before surgery. If the measurement is less than 5 mm, consider either performing a staged approach with future site development using a trephine/

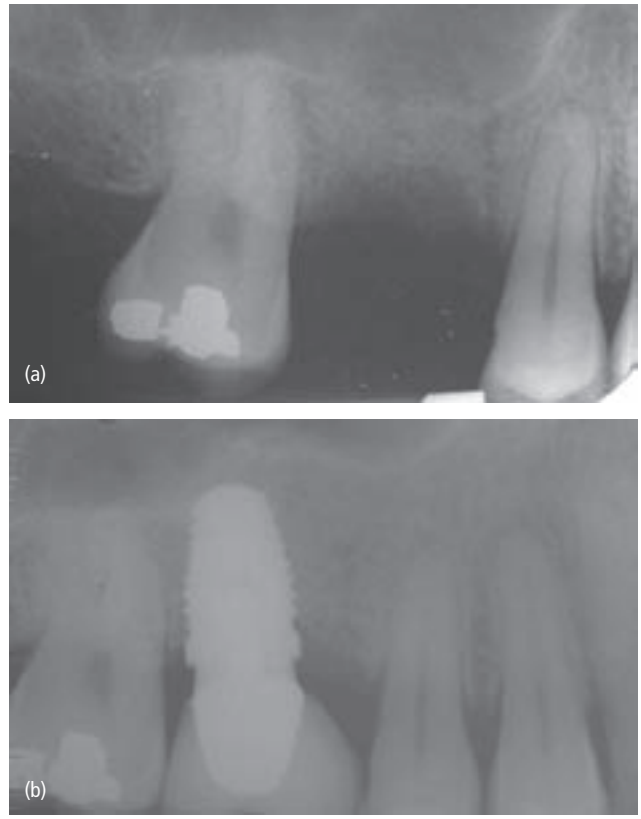


Fig. 17.8 (a) Preclinical view of maxillary right first molar site which was to receive an implant with simultaneous bone-added osteotome sinus floor elevation. (b) A tapered implant had been placed and the radiograph was taken at the fourth year postloading. Platform switching was performed to maintain crestal bone height.

osteotome technique (23) (Fig. 17.9a–f) or placing the implant simultaneous to a lateral window sinus elevation. If one is still intent on simultaneous implant placement with BAOSFE where the initial dimension of bone is less than 5 mm beneath the sinus floor, then undersizing at the preparation is recommended to attain coronal primary stability (52).

Less dense bone is also a concern. In situations where poorer bone quality is encountered, greater use of the osteotome might be considered versus drilling of the site with the hope that compression of the bed will lead to denser bone and greater implant stability. An alternative to this might be to underprepare the site with the drill and use a substantially larger diameter implant to facilitate better primary stability.

The malleting process may also diminish primary implant stability, particularly in denser bone. Owing to the imprecise nature and the vibration that occurs with BAOSFE site preparation, it is more likely that overwidening of the osteotomy site may occur. Again, it may be

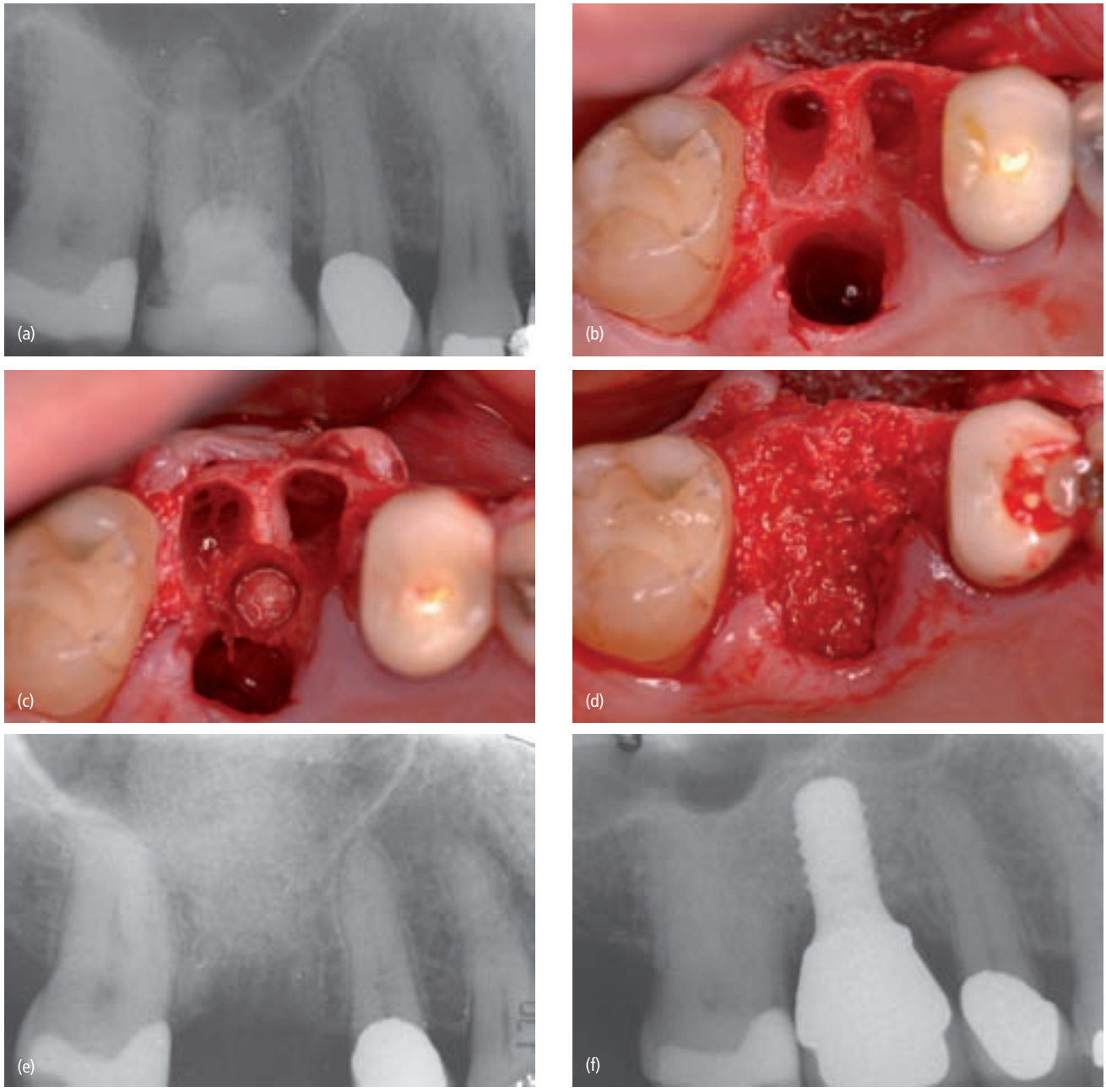


Fig. 17.9 (a) Pretreatment radiograph of the maxillary right first molar, which is not treatable. (b) Occlusal view after removal of the first molar. (c) A trephine has been used at the furcation bone to allow for future site development. The osteotomes have been used to implode the bone core at the prior furcation bone septum. (d) The site is grafted with mineralized freeze-dried bone. (e) Radiograph taken at the time of elevation suggesting favorable elevation of the inferior sinus wall. (f) This radiograph was exposed at 1 year after loading of the implant. The area appears to have a favorable outcome to care.

better to underprepare the site by one osteotome size, complete the sinus grafting and elevation, increase the opening of the osteotomy site with a wider diameter drill, and then place the implant. An alternative method for avoiding overwidening is to use the drill unit as much as possible owing to its higher precision for site preparation.

Premature loading

If a patient will be wearing an interim removable appliance, it is imperative that no forces be transmitted to the healing implant. This can be avoided by either submerging the implant beneath the tissue as a two-staged procedure and/or by checking for any pressure to the site from the prosthesis and removing any contact it may have with the implant. Rest seats can be placed into the adjacent teeth and occlusal stops could be included in the design of any transitional removable appliance that will be worn. If multiple implants are to be placed with BAOSFE, then transitional implants could be considered to support a fixed interim prosthesis.

Membrane tear or perforation

Preventing membrane tears is best accomplished by not extending the osteotome beyond the sinus boundary. After infracturing the inferior wall, one should not tap beyond the osteotome mark corresponding to where this occurred. Some companies manufacture stops for their osteotomes to prevent this from occurring. Clinicians must be accurate in their presurgical measurements to stop short of the sinus wall by approximately 1 mm, particularly when drilling (43). The use of piezoelectric units to facilitate the infracture of the sinus wall may be considered. They provide a gentler, more controlled force which may be better tolerated by the patient.

Membrane tears may also occur when excessive force is applied during the malleting of the graft. Cavicchia *et al.* (22) and others have advocated the placement of a collagen membrane into the osteotomy site to help cushion the graft being tapped into the space created beneath the sinus membrane. This would also obviate the concern of graft particle sharpness causing membrane tear. Also, when placing the implant, the osteotomy can be partially filled with graft to provide additional cushioning to the membrane elevation (43).

Computed tomography should be considered before the procedure to elucidate anatomic considerations that may increase the likelihood of perforation, i.e. septae and the collateral wall of the nose (43). This may aid the clinician in determining how to approach the sinus procedure.

Adhering to the $2x - 2$ rule for anticipated maximum sinus elevation will also reduce the likelihood of membrane tear. Fugazzotto (53) postulated that the maximum height for sinus lift is two times the measurement of the osseous crest to the inferior sinus wall minus 2 mm. Following this formula may reduce incorrect estimates of what can be accomplished.

An endoscopic approach to sinus elevation may be one additional method to avoid tearing the sinus membrane or at least evaluate if this has occurred. Nkenke *et al.* (14) recommended that when greater than 3 mm of elevation is to be attempted, the use of an endoscope should be considered with concomitant dissection of the membrane from the sinus floor.

Benign paroxysmal positional vertigo, headache, and labyrinthitis

The sequelae of headache, labyrinthitis, and BPPV with osteotome use can be consequential, especially if they interfere with a patient's lifestyle or work schedule. Using newer techniques or devices such as osteotome inserts for the low-speed drill that reduce or avoid malleting should minimize the complications of postsurgical headache and/or BPPV. Another consideration includes avoiding hyperextension of the neck when performing the procedure.

Poor patient experience

The greatest complaint expressed by patients who undergo osteotome sinus floor elevation is related to the intraoperative malleting. Diserens *et al.* (51) demonstrated this in their article where patients were interviewed about their experience. The authors suggested that patients who will undergo the osteotome procedure should be informed in detail about what might be encountered. It is always easier to manage patient expectation than surprises. Furthermore, techniques that obviate the use of the malleting may be better embraced by patients. Reiser *et al.* (43) recommended drilling the site to 1 mm short of the sinus wall to limit the amount of traumatic tapping.

The technique of internal sinus lift has evolved over time and will continue to do so. Clinicians will need to evaluate what aspects of care should be retained and which modifications and/or new technologies should be embraced. New devices have come to the market, all of which claim to reduce complications, ease the infracture of the inferior sinus wall, improve on osteotomy site preparation, and reduce postoperative morbidity. Techniques and devices such as the endoscopically controlled sinus lift (14), hydraulic sinus lift (15), MIAMBE (16, 17), internal sinus manipulation (54), and piezoelectric-aided sinus floor elevation (55, 56) (Fig. 17.10a–h) all show promise. However, until controlled prospective studies appear to validate their use, one must proceed with caution.

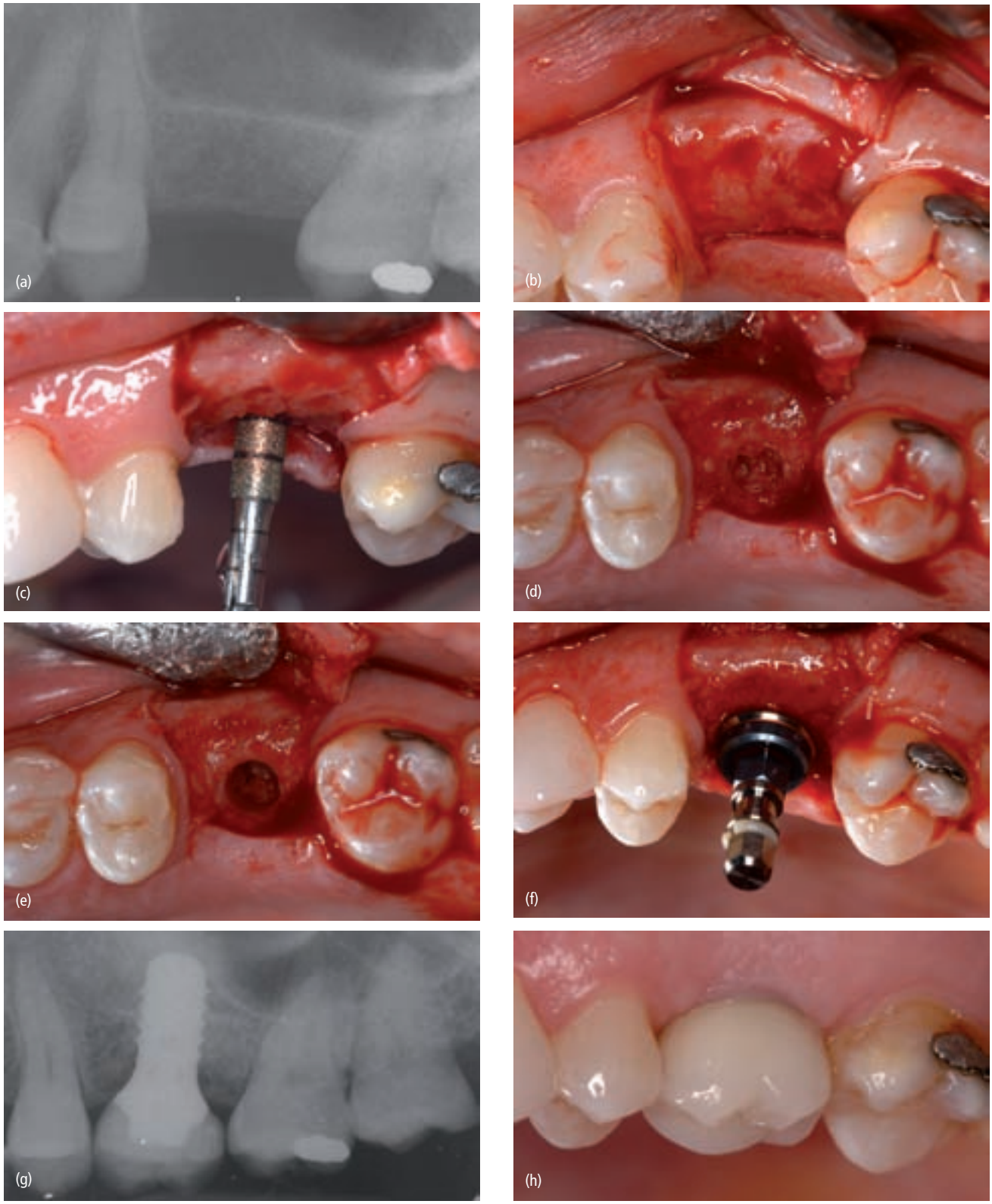


Fig. 17.10 (a) Pretreatment radiographic view of the maxillary left first molar which has 5 mm of bone to the sinus. (b) Exposure of the edentulous ridge. (c) Use of the piezoelectric unit to create the osteotomy and infracture the sinus wall. (d) Placement of mineralized freeze-dried bone to augment the sinus. (e) Elevation of the sinus membrane occurs by condensing the graft into the sinus using either a piezoelectric tip that facilitates the graft being elevated or the osteotomes. (f) Placement of the implant into the osteotomy after the sinus elevation. (g) One year postplacement radiograph suggesting good elevation of the sinus wall and stability of the peri-implant bone. (h) Implant restoration at 1 year postsurgery. (Prosthetic treatment was performed by Jonathon Glatt, DMD, Yardley, Pennsylvania, USA.)

Management of complications

Again, the management of complications is best achieved by preventing them. Complications that have occurred in many cases are difficult to treat. However, the following is a list of management tips.

When infection occurs at the site of an implant, the first line of treatment is to place the patient on a bactericidal antibiotic such as amoxicillin, amoxicillin/clavulanate, or levofloxacin. Should the infection be persistent, culturing of the site may be necessary in selecting additional antibiotics and the patient may need to be referred to an otolaryngologist for further case management. If there is a concern that the graft is infected or even the source of that infection then its removal may be necessary. The use of local delivery agents such as povidone iodine may be of further benefit in treating the ailing site. However, severe infection often requires that the implant be removed.

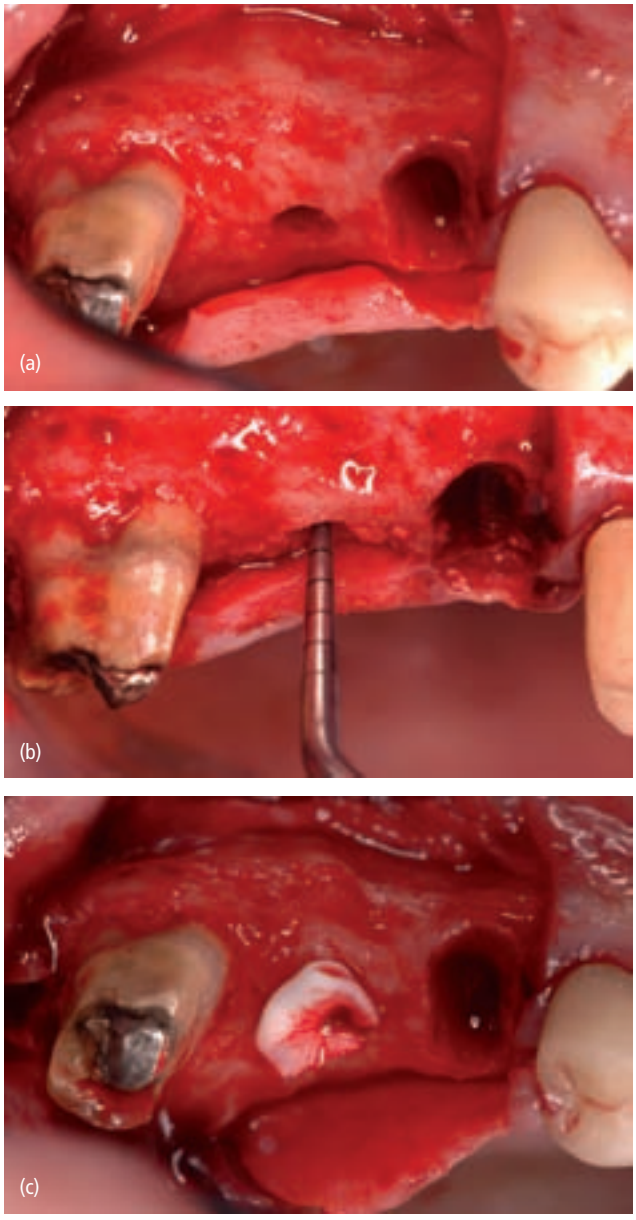
If primary stability is not achieved upon implant placement, then the surgeon may wish to place a wider implant or try to stabilize the implant with a bone replacement graft. A graft that is demineralized versus one that is mineralized may be the material of choice in this situation. The clinician backs out the loose implant, places some demineralized graft particles into the osteotomy, and attempts to rethread the implant into the site. A mineralized graft may interfere with smooth insertion of the implant, causing wobble and possible suboptimal implant placement. The use of a wider implant to gain the needed stability may be another option to increase primary stability. While this option appears to be a good one on first impression, the problem could arise that the added site preparation would reduce the buccal–palatal bone dimension, leaving inadequate blood supply to maintain crestal bone height and implant stability. If none of these options works, the implant should be removed and bone replacement graft should be placed into the osteotomy with membrane coverage. The clinician should allow 4–6 months for healing of the area before placing another implant. The clinician has to consider the risk of possible implant migration into the sinus if there is poor stability at the time of placement. If migration does occur, then removal of the implant will be necessary to avoid further adverse consequences for the patient, e.g. sinusitis or sinus infection. Implant removal in these cases usually requires a lateral window approach.

Premature loading of the implant is difficult to treat other than by further relieving the cause of the loading or instructing the patient to avoid wearing the interim prosthesis.

If there is concern that a perforation or a tear of the membrane may have occurred, the placement of a collagen membrane into the osteotomy may help to repair this and avoid graft particles migrating into the sinus. Nkenke *et al.* (14) believed that the only true way to assess this is through endoscopy. Reiser *et al.* (43) classified the sinus tears as either class I (≤2 mm with exposure of the implant into the sinus cavity and loss of doming) or class II perforations (≥2 mm). The authors believed that in the case of class I perforations, the remaining graft and blood clot would serve as a vital scaffold allowing spontaneous healing of the membrane, while with class II perforations (12% of the sites) implant failure would be inevitable. So, if the tear is beyond 2 mm, the clinician should consider repairing the tear with collagen at the tear, followed by grafting and primary closure of the flap. An alternative may be to perform a lateral window approach for repair, along with aborting the placement of the implant. If the clinician believes that a microtear or tear has occurred, the patient may be placed on a systemic antibiotic with bactericidal properties along with an antihistamine, e.g. diphenhydramine, loratadine, or fexofenadine, and a decongestant, e.g. pseudophedrine. The patient should be instructed to refrain as much as possible from blowing his or her nose. Should the tear progress to create a subsequent patent oral–antral communication, it may be necessary to remove the implant and attempt to repair this area. Repair involves removal of the implant to see whether the sinus opening will close on its own. In the interim, the patient is instructed to rinse with a 50:50 diluted hydrogen peroxide–water solution, gently lavaging the osteotomy, to use systemic antibiotics such as amoxicillin/clavulanate or levofloxacin. The repair may involve the use of a collagen membrane over the window opening, the use of a graft material into the osteotomy covered by another collagen membrane, along with advancing the flap to gain primary closure or the use of a palatal flap to gain closure. If the clinician is not experienced in this area of care, the patient should be referred to someone with such experience or to an otolaryngologist.

If BPPV has occurred, the use of the Epley maneuver can successfully manage the problem, particularly if the particles are located in the posterior semicircular canal (49, 57). The patient should be referred to an otolaryngologist for evaluation and treatment.

Finally, poor patient experience is best managed by giving the patient a realistic expectation of what may be encountered. This is best accomplished by taking the time to inform the patient of what may be involved in their care and of the potential adverse consequences.



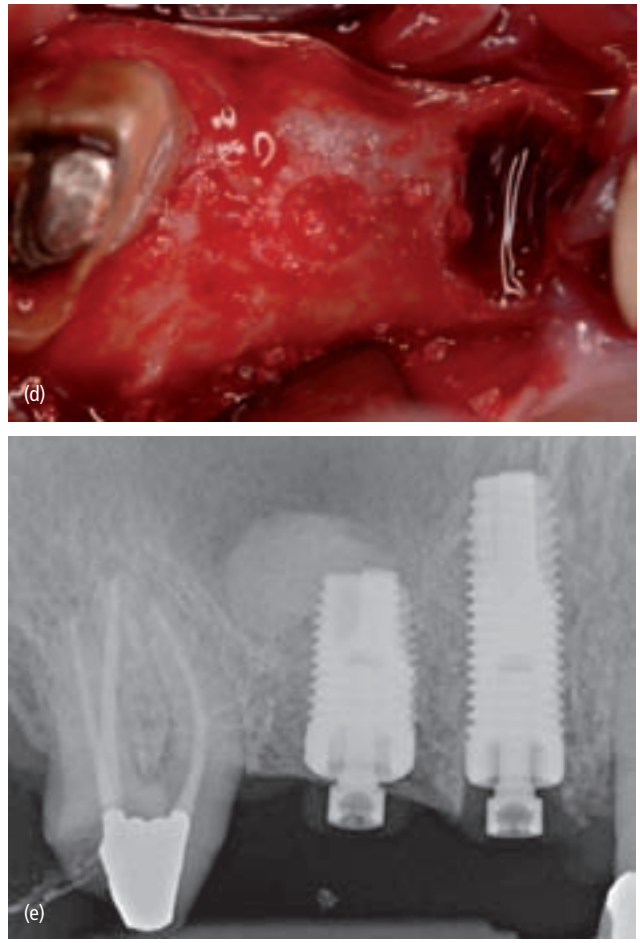


Fig. 17.11 (a) Osteotomy site created using an implant handpiece with a twist drill. (b) Piezoelectric handpiece with a round diamond ball used to infracture the sinus wall. (c) Collagen membrane is inserted into the site before placing the graft. (d) Graft material is placed into the osteotomy after the collagen membrane. (e) Sinus area after elevation with a mineralized bone replacement graft and implant placement. Note the rounded doming of the sinus lift, which suggests that there have been no perforations or tears of the membrane.

Take-home hints

- When preparing to treat a patient with an osteotome approach to sinus elevation, there should be a minimum of 5 mm of bone beneath the sinus. The $(2x - 2)$ rule (54), where x is the dimension of bone beneath the sinus, should be used when determining what is a reasonable goal for sinus elevation.
- The site should initially be prepared just short of the sinus wall with an implant handpiece. Radiographic verification of this should be performed using a radiopaque calibrated measuring device inserted into the osteotomy.
- The osteotomy should be undersized since the use of the osteotomes may widen the site, thereby reducing the primary stability of the implant when it is placed.
- A piezoelectric handpiece with a round diamond ball (Fig. 17.11a, b) should be considered to infracture the wall of the sinus initially. The advantage of this approach is avoiding the malleting that creates many of the adverse sequelae, while the piezoelectric tip helps to reduce the likelihood of tearing the membrane.
- Before placing the graft into the osteotomy, a collagen membrane/plug (Fig. 17.11c) should be inserted into the osteotomy as Cavicchia *et al.* (22)

recommended. This may help to avoid a perforation preventing graft exfoliation and loss (Fig. 17.11d, e). If the amount of sinus lift may be less than 2 mm, consideration should be given to using the collagen alone without a graft.

- To avoid sinus perforation, the osteotomes should not be tapped or advanced beyond the length of the final drill.
- Make sure that no loading forces are placed on the implant at the time of placement. Any provisional appliances should be checked in function to avoid loss of the implant owing to premature loading.

Acknowledgment

The author wishes to thank Dr Michael Toffler for his review of this manuscript.

References

1. Wallace SC, Froum SJ. Effect of maxillary sinus augmentation on the survival of endosseous dental implants. A systematic review. *Ann Periodontol* 2003; **8**: 328–43.
2. Del Fabbro M, Testori T, Francetti L, Weinstein R. Systemic review of survival rates for implants placed in the grafted maxillary sinus. *Int J Periodontics Restorative Dent* 2004; **24**: 565–77.
3. Aghaloo TL, Moy PK. Which hard tissue augmentation techniques are the most successful in furnishing bony support for implant placement? *Int J Oral Maxillofac Implants* 2007; **22** (Suppl): 49–70.
4. Summers RB. The osteotome technique: Part 3: Less invasive methods of elevating the sinus floor. *Compend Contin Educ Dent* 1994; **15**: 698–708.
5. Horowitz RA. The use of osteotomes for sinus augmentation at the time of implant placement. *Compend Contin Educ Dent* 1997; **18**: 441–7, 450–2.
6. Cosci F, Luccioli M. A new sinus lift technique in conjunction with placement of 265 implants: a 6-year retrospective study. *Implant Dent* 2000; **9**: 363–8.
7. Leonetti JA, Rambo HM, Throndson RR. Osteotome sinus elevation and implant placement with narrow size bioactive glass. *Implant Dent* 2000; **9**: 177–82.
8. Saadoun AP, Le Gall MG. Implant site preparation with osteotomes: principles and clinical application. *Pract Periodontics Aesthet Dent* 1996; **8**: 453–63.
9. Toffler M. Osteotome-mediated sinus floor elevation: a clinical report. *Int J Oral Maxillofac Implants* 2004; **19**: 266–73.
10. Nedir R, Bischof M, Vazquez L, Szmukler-Moncler S, Bernard J-P. Osteotome sinus floor elevation without grafting material: a 1-year prospective pilot study with ITI implants. *Clin Oral Implant Res* 2006; **17**: 679–86.
11. Bruschi GB, Scipioni A, Calesini G. Bruschi E. Localized management of sinus floor with simultaneous implant placement: a clinical report. *Int J Oral Maxillofac Implants* 1998; **13**: 219–26.
12. Winter AA, Pollack AS, Odrich RB. Placement of implants in the severely atrophic posterior maxilla using localized management of the sinus floor: a preliminary study. *Int J Oral Maxillofac Implants* 2002; **17**: 687–95.
13. Li TF. Sinus floor elevation: a revised osteotome technique and its biological concept. *Compend Contin Educ Dent* 2005; **26**: 619–30.
14. Nkenke E, Schlebel A, Schultze-Mosgau S, Neukam FW, Wiltfang J. The endoscopically controlled osteotome sinus floor elevation: a preliminary prospective study. *Int J Oral Maxillofac Implants* 2002; **17**: 557–66.
15. Chen L, Cha J. Minimally invasive hydraulic sinus condensing technique. *J Periodontol* 2005; **76**: 482–91.
16. Kfir E, Kfir V, Mijiritsky E, Rafaeloff R, Kaluski E. Minimally invasive antral membrane balloon elevation followed by maxillary bone augmentation and implant fixation. *J Oral Implantol* 2006; **32**: 26–33.
17. Kfir E, Kfir V, Eliav E, Kaluski E. Minimally invasive antral membrane balloon elevation: report of 36 procedures. *J Periodontol* 2007; **78**: 2032–5.
18. Emmerich D, Att W, Stappert C. Sinus floor elevation using osteotomes: a systematic review and meta-analysis. *J Periodontol* 2005; **76**: 1237–51.
19. Rosen PS, Summers R, Mellado JR, Salkin LM, Shanaman RH, Marks MH, Fugazzotto PA. The bone-added osteotome sinus floor elevation technique: multi-center retrospective report of consecutively treated patients. *Int J Oral Maxillofac Implants* 1999; **14**: 853–8.
20. Coatoam GW, Krieger JT. A four-year study examining the results of indirect sinus augmentation procedures. *J Oral Implant* 1997; **23**: 117–27.
21. Deporter D, Todescan R, Caudry S. Simplifying management of the posterior maxilla using short, porous-surfaced dental implants and simultaneous indirect sinus elevation. *Int J Periodontics Restorative Dent* 2000; **20**: 476–85.
22. Cavicchia F, Bravi F, Petrelli G. Localized augmentation of the maxillary sinus floor through a coronal approach for the placement of implants. *Int J Periodontics Restorative Dent* 2001; **21**: 475–85.
23. Fugazzotto PA, De Paoli S. Sinus floor augmentation at the time of maxillary molar extraction: success and failure rates of 137 implants in function for up to 3 years. *J Periodontol* 2002; **73**: 39–44.
24. Fugazzotto PA. Immediate implant placement following a modified trephine/osteotome approach: success rates of 116 implants to 4 years in function. *Int J Oral Maxillofac Implants* 2002; **17**: 113–20.
25. Zitzmann NU, Schaerer P. Sinus elevation procedures in the resorbed posterior maxilla. Comparison of the crestal and lateral approaches. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1998; **85**: 8–17.
26. Shalabi MM, Manders P, Mulder J, Jansen JA, Creugers NH. A meta-analysis of clinical studies to estimate the 4.5-year survival rate of implants placed with the osteotome technique. *Int J Oral Maxillofac Implants* 2007; **22**: 110–16.
27. Komarnyckyj OG, London RM. Osteotome single-stage dental implant placement with and without sinus elevation:

a clinical report. *Int J Oral Maxillofac Implants* 1998; **13**: 799–804.
28. Rodoni LR, Glauser R, Feloutzis A, Hammerle CH. Implants in the posterior maxilla: a comparative clinical and radiologic study. *Int J Oral Maxillofac Implants* 2005; **20**: 231–7.
29. Strietzel FP, Nowak M, Kuchler I, Friedmann A. Peri-implant alveolar bone loss with respect to bone quality after use of the osteotome technique: results of a retrospective study. *Clin Oral Implants Res* 2002; **13**: 508–13.
30. Ferrigno N, Laureti M, Fanali S. Dental implants placement in conjunction with osteotome sinus floor elevation: a 12-year life-table analysis from a prospective study on 588 ITI® implants. *Clin Oral Implant Res* 2006; **17**: 194–205.
31. Tan WC, Lang NP, Zwahlen M, Pjetursson BE. A systematic review of the success of sinus floor elevation and survival of implants inserted in combination with sinus floor elevation. *J Clin Periodontol* 2008; **35** (Suppl 8): 241–54.
32. Leblebicioglu B, Ersanli S, Karabuda C, Tosun T, Gokdeniz H. Radiographic evaluation of dental implants placed using an osteotome technique. *J Periodontol* 2005; **76**: 385–90.
33. Krenmair G, Krainhofner M, Schmid-Schwap M, Piehslinger E. Maxillary sinus lift for single implant-supported restorations: a clinical study. *Int J Oral Maxillofac Implants* 2007; **22**: 351–8.
34. Zhao BD, Wang YH, Xu JS, Zheng J, Gong DL, Yu Y. Clinical study of maxillary sinus floor elevation with simultaneous placement of implants from the top of alveoli. *Shanghai Kou Qiang Yi Xue* 2007; **16**: 480–3.
35. Pjetursson BE, Rast C, Brägger U, Zwahlen M, Lang NP. Maxillary sinus floor elevation using the osteotome technique with or without grafting material. Part I – Implant survival and patient's perception. *Clin Oral Implants Res* 2009; **20**: 667–76.
36. Jaffin RA, Berman CL. The excessive loss of Brånemark fixtures in type IV bone: a 5-year analysis. *J Periodontol* 1991; **62**: 2–4.
37. Hahn J. Clinical uses of osteotomes. *J Oral Implantol* 1999; **25**: 23–9.
38. Büchter A, Kleinheinz J, Joos U, Meyer U. Primary implant stability with different bone surgery techniques. An *in vitro* study of the mandible of the minipig. *Mund Kiefer Gesichtshir* 2003; **7**: 351–5 [in German].
39. Büchter A, Kleinheinz J, Wiesmann HP, Jayaranan M, Joos U, Meter U. Interface reaction at dental implants inserted in condensed bone. *Clin Oral Implants Res* 2005; **16**: 509–17.
40. Büchter A, Kleinheinz J, Wiesmann HP, Kersken J, Nienkemper M, von Weyhrother H, *et al.* Biological and biomechanical evaluation of bone remodeling and implant stability after using an osteotome technique. *Clin Oral Implants Res* 2005; **16**: 1–8.
41. Regev E, Smith RA, Perrott DH, Pogrel MA. Maxillary sinus complications related to endosseous implants. *Int J Oral Maxillofac Implants* 1995; **10**: 451–61.
42. Galindo P, Sanchez-Fernandez E, Avila G, Cutando A, Fernandez JE. Migration of implants into the maxillary sinus: two clinical cases. *Int J Oral Maxillofac Implants* 2005; **20**: 291–5.
43. Reiser GM, Rabinowitz Z, Bruno J, Damoulis PD, Griffin TJ. Evaluation of the maxillary sinus membrane response following elevation with the crestal osteotome technique in human cadavers. *Int J Oral Maxillofac Implants* 2001; **16**: 833–40.
44. Pommer B, Unger, Sütö D, Hack, Watzek G. Mechanical properties of the Schneiderian membrane *in vitro*. *Clin Oral Implant Res* 2009; **20**: 633–7.
45. Baumann A, Ewers R. Minimally invasive sinus lift. Limits and possibilities in the atrophic maxilla. *Mund Kiefer Gesichtschir* 1999; **3** (Suppl 1): S70–3 [in German].
46. Saker M, Ogle O. Benign paroxysmal positional vertigo subsequent to sinus lift via closed technique. *J Oral Maxillofac Surg* 2005; **63**: 1385–17.
47. Di Girolamo M, Napolitano B, Arullani CA, Bruno E, Di Girolamo S. Paroxysmal positional vertigo as a complication of osteotome sinus floor elevation. *Eur Arch Otorihnolaryngol* 2005; **262**: 631–3.
48. Pérez-Garrigues H, Mateos Fernández M, Peñarrocha M. Benign paroxysmal positional vertigo secondary to surgical maneuvers on superior maxilla. *Acta Otorrinolaringo Esp* 2001; **52**: 343–6 [in Spanish].
49. Peñarrocha-Diago M, Rambia-Ferrer J, Perez V, Pérez-Garrigues H. Benign paroxysmal positional vertigo secondary to placement of maxillary implants using the alveolar expansion technique with osteotomes: a study of 4 cases. *Int J Oral Maxillofac Implants* 2008; **23**: 129–32.
50. Oghalai JS, Mandolidis S, Barth JL, Stewart MG, Jenkins HA. Unrecognized benign paroxysmal positional vertigo in elderly patients. *Otolaryngol Head Neck Surg* 2000; **122**: 630–4.
51. Diserens V, Merickse E, Schäppi P, Mericske-Stern R. Transcrestal sinus floor elevation: report of a case series. *Int J Periodontics Restorative Dent* 2006; **26**: 151–9.
52. Shalabi MM, Wolke JGC, Jansen JA. The effects of implant surface roughness and surgical technique on implant fixation in an *in vitro* model. *Clin Oral Implants Res* 2006; **17**: 172–8.
53. Fugazzotto P. Treatment options following single-rooted tooth removal: a literature review and proposed hierarchy of treatment selection. *J Periodontol* 2005; **76**: 821–31.
54. Yamada JM, Park HJ. Internal sinus manipulation (ISM) procedure: a technical report. *Clin Implant Dent Relat Res* 2007; **9**: 128–35.
55. Wainwright MA, Troedhan A, Kurrek A. The Intralift™: a new minimal invasive ultrasonic technique for sinus grafting procedures. *Implants Int Mag Implantol* 2007; **8**(3): 30–4.
56. Wainwright MA, Troedhan A, Kurrek A. Minimal invasives Verfahren zur Augmentation des Sinus des maxillaries. *Implantol J* 2007; **7**: 43–6.
57. Hornubia V, Baloh RW, Harris MR, Jacobson KM. Paroxysmal positional vertigo syndrome. *Am J Otol* 1999; **20**: 465–70.

Chapter 18

Implant complications related to immediate implant placement into extraction sites

Barry D. Wagenberg DMD *and Stuart J. Froum* DDS

Introduction

Length of treatment and cost are two of the most common objections to implant dentistry. Traditionally, implants were placed into well-formed ridges with a one- or two- stage unloaded protocol (1, 2). Today, it is often necessary to re-establish architecture either before or during implant placement. This can be done with a number of augmentation procedures including block grafts (3), guided bone regeneration (GBR) (4), interpositional grafts (5), and distraction osteogenesis (6).

In two separate publications, Schulte *et al.* (7) and Lazarra (8) introduced the concept of placement of implants into fresh extraction sites. Controversy existed related to the success rate of implants placed with this protocol. To date, several literature reviews have been published demonstrating similar survival rates with immediate implant placement (IIP) and implants placed into healed edentulous areas (9–11). Many clinicians feel that a two-stage approach involving extraction, ridge augmentation and a healing period of 4–12 months will enhance the implant success rate. However, this approach not only prolongs the time for eventual tooth replacement and return to function and esthetics, but also increases the cost to the patient. Placement of implants into infected extraction sites is even more controversial and avoided by most clinicians. Implant replacement of maxillary and mandibular molars using an IIP protocol is also often avoided by most clinicians. In all of these cases, with proper surgical management the success rates are also similar to implant placement into edentulous or previously augmented sites (12, 13).

Placement of implants at the time of extraction of the natural tooth offers many advantages over delayed placement (Fig. 18.1a–e). These include improved healing without flap advancement, decreased treatment time, fewer surgical procedures, decreased cost, and decreased discomfort. These advantages have been discussed in numerous studies all reporting high implant survival rates for IIP (14–24).

Complications with the IIP protocol can occur, as they do with all implant placement protocols. However, the most common complications that occur with IIP after extraction of the natural tooth include:

- poor implant positioning
- membrane exposure during healing
- inadequate bands of keratinized tissue after healing
- gingival recession
- implant failure
- unacceptable esthetic outcomes.

Etiology and prevention

Poor implant positioning

Poor implant positioning could occur owing to the failure of the clinician to initiate the osteotomy in the correct position (Figs 18.2a–j, 18.3a–d) (see Chapters 8 and 9). The ideal position is along the lingual incline in a maxillary anterior tooth, at the apex of the socket for a premolar, and in the area of the interdental septum for a molar. The standard round entry bur often cannot guide the 2 mm drill into the ideal position after the natural tooth is extracted. Use of a pointed and very sharp entry bur will make the initial entry and position more reliable (Fig. 18.4) (long bur: Nobel Biocare, Yorba Linda, CA, USA; short bur: 3i, Palm Beach Gardens, FL, USA). Careful placement of the osteotomy as described in the following procedural section is important (24). It is critical to know in advance what type of final restoration is planned for the sites and the location of the central fossa or cingulum.

For a screw-retained restoration the implant should exit in the central fossa of the posterior teeth and in the cingulum area of the anterior teeth.

For a cemented restoration the implant should exit in the central fossa of the posterior teeth and in the incisal area of anterior teeth.

For removable dentures the implant should exit just palatal to the teeth in the anterior and posterior and may be better positioned between two teeth. This will decrease the chances of the denture teeth being dislodged.

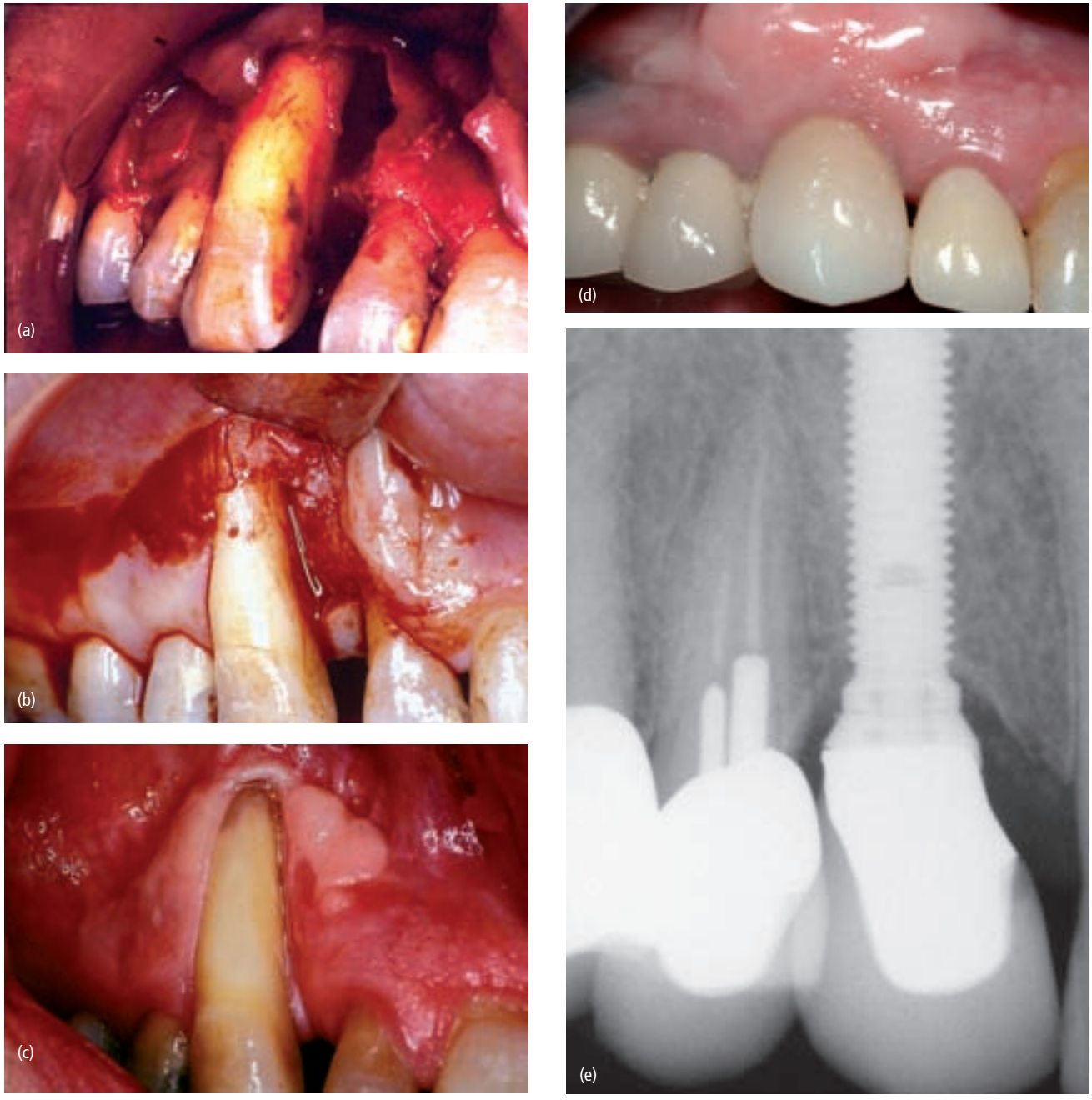
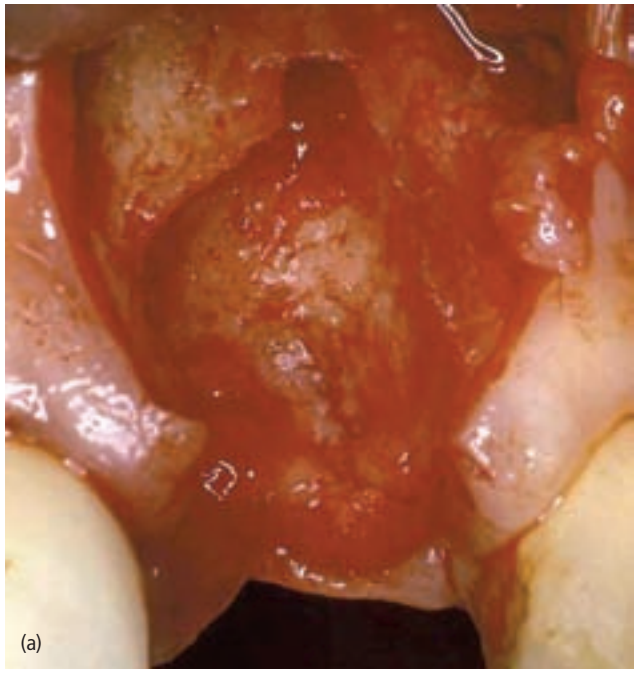
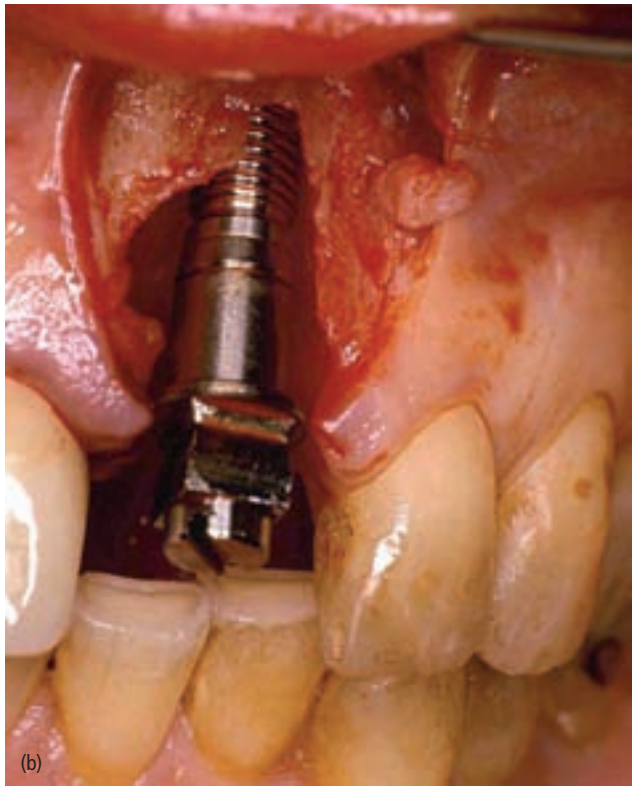


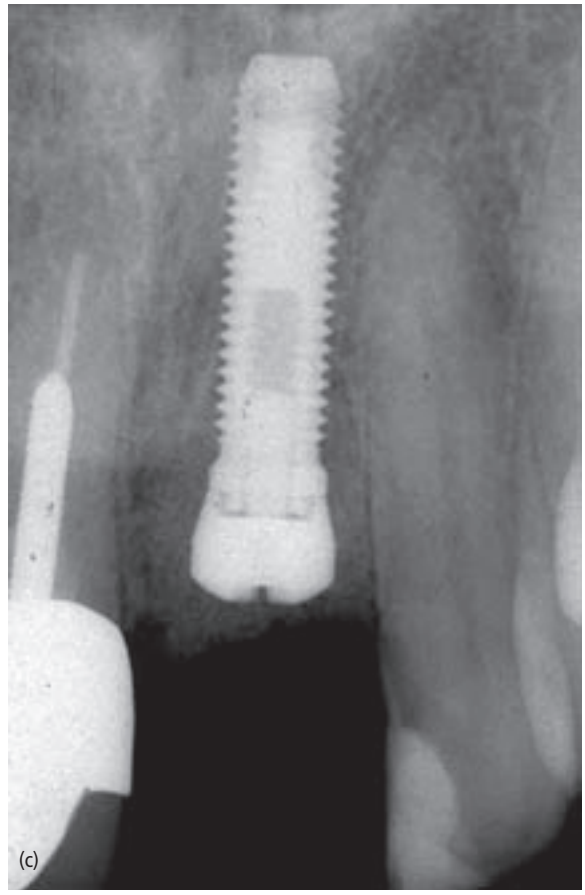
Fig. 18.1 (a) A deep defect around the maxillary right cuspid wrapped around to the palatal aspect of the tooth. (b) An autogenous bone graft resulted in significant bone regeneration as seen at re-entry. (c) The labial aspect of the cuspid was significantly exposed but did not show owing to a low smile line. After 11 years the cuspid developed significant attachment loss and it was determined that the tooth was hopeless and required extraction. (d) The tooth was extracted, an implant placed, and an allograft and PG910 membrane were used in an attempt to regenerate the lost labial plate of bone. This was done at the same visit as the extraction. The implant restoration has improved the esthetics of this tooth and has been functioning for more than 4 years. (e) Radiograph taken 4 years after restoration.

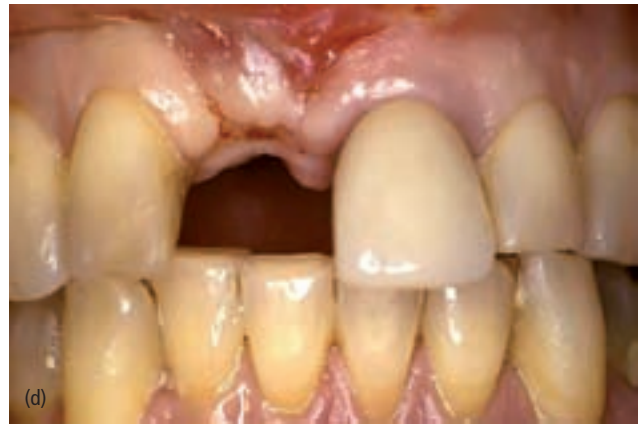
Membrane exposure during healing

Membrane exposure during healing is a common occurrence. Depending on the type of membrane used this may or may not be significant. With most membrane systems it is important to have primary flap closure. Proper advancement of the flap without tension and use of a suture material which will help to retain the flaps in place during the initial stages of healing are recommended. Membrane exposure with absorbable membranes such as Polyglactin 910 (PG910) (Vicryl, Ethicon; Johnson and Johnson, Somerville, NJ, USA) or collagen membranes usually does not significantly affect the results. The PG910 membrane breaks down in acid form









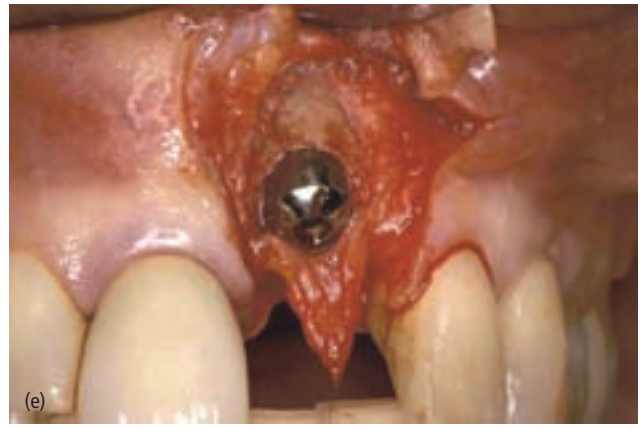
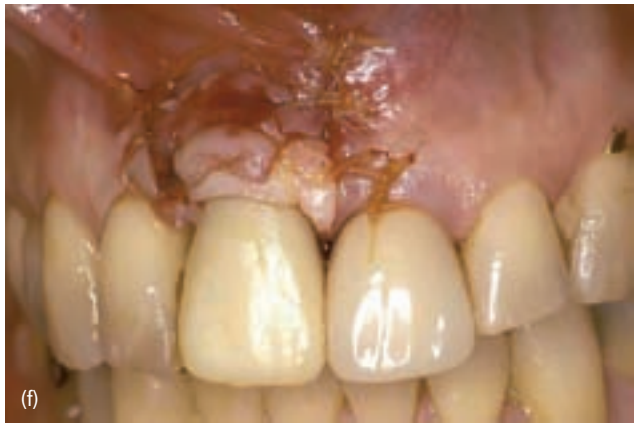
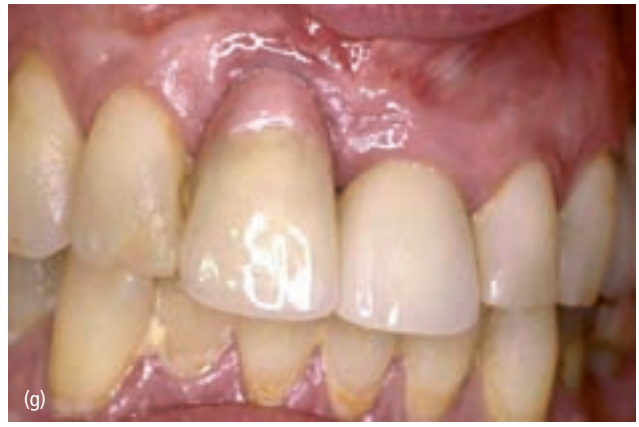
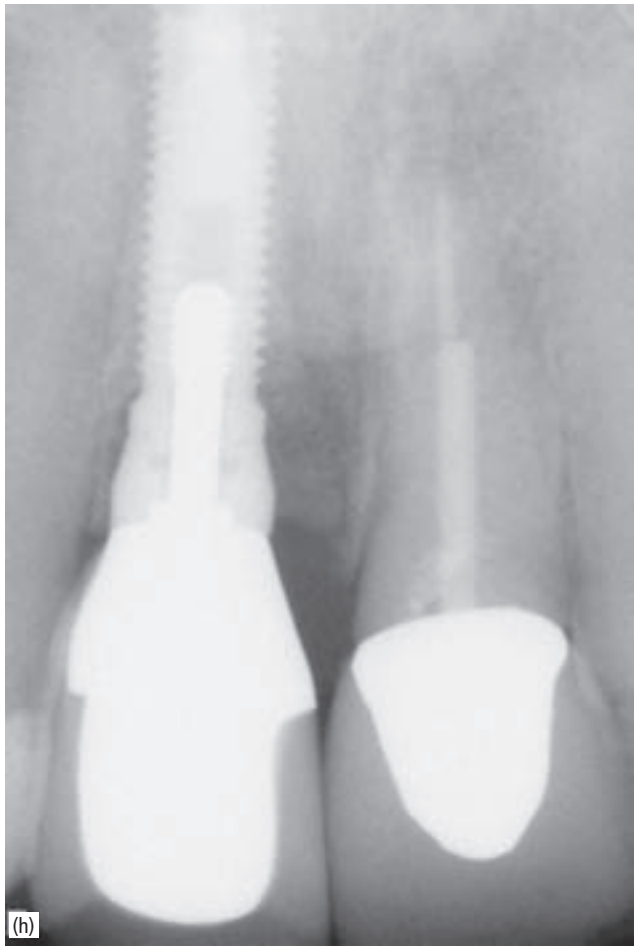
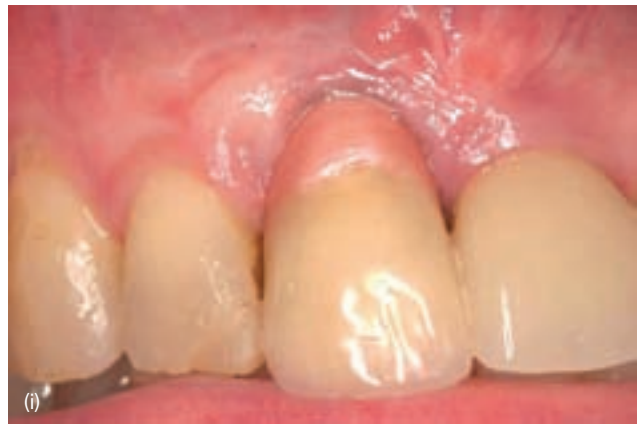


Fig. 18.2 (a) The maxillary right central incisor was removed, leaving a significant bone defect. (b) An implant was placed and a bone graft and PG910 membrane were used to regenerate the lost alveolus. (c) Radiograph of the implant placed on the day of surgery. A healing abutment was placed to make access easier at the second stage. (d) The area appeared to heal well with adequate keratinized tissue. (e) Bone regeneration is evident at the second stage surgery.









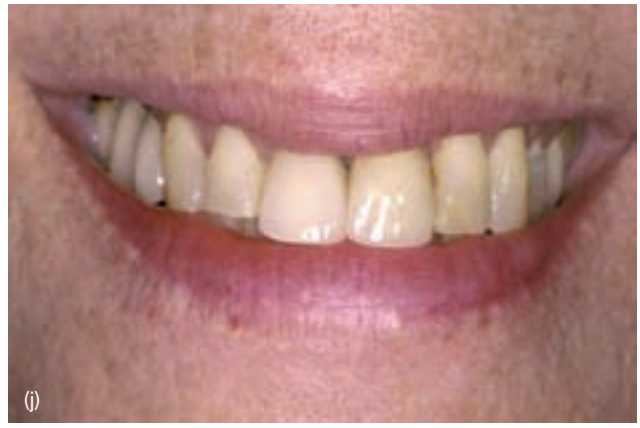


Fig. 18.2 ***(cont'd)*** (f) Owing to the labial placement of the implant, apical recession of the tissue occurred. A connective tissue graft was placed but did not achieve the desired results. (g) Pink porcelain was used to help mask the tissue height discrepancies. (h) Radiograph taken 12 years after restoration. (i) Clinical photograph taken 12 years after restoration. (j) The patient's smile line did not show the uneven gingival levels.

and bacterial growth over it is minimal. These membranes do not require advancement of the flaps for membrane coverage, as it is not critical to success. After the membrane dissolves there is usually an adequate volume of keratinized tissue between the original flap margins when the flaps are not advanced. In certain circumstances, such as in smokers, it is recommended to advance the flap even with this membrane as the tissues tend to shrink more in smokers and plaque accumulation is usually increased.

Inadequate bands of keratinized tissue after healing

The gingival marginal levels around implant restorations tend to be maintained over time more coronally when

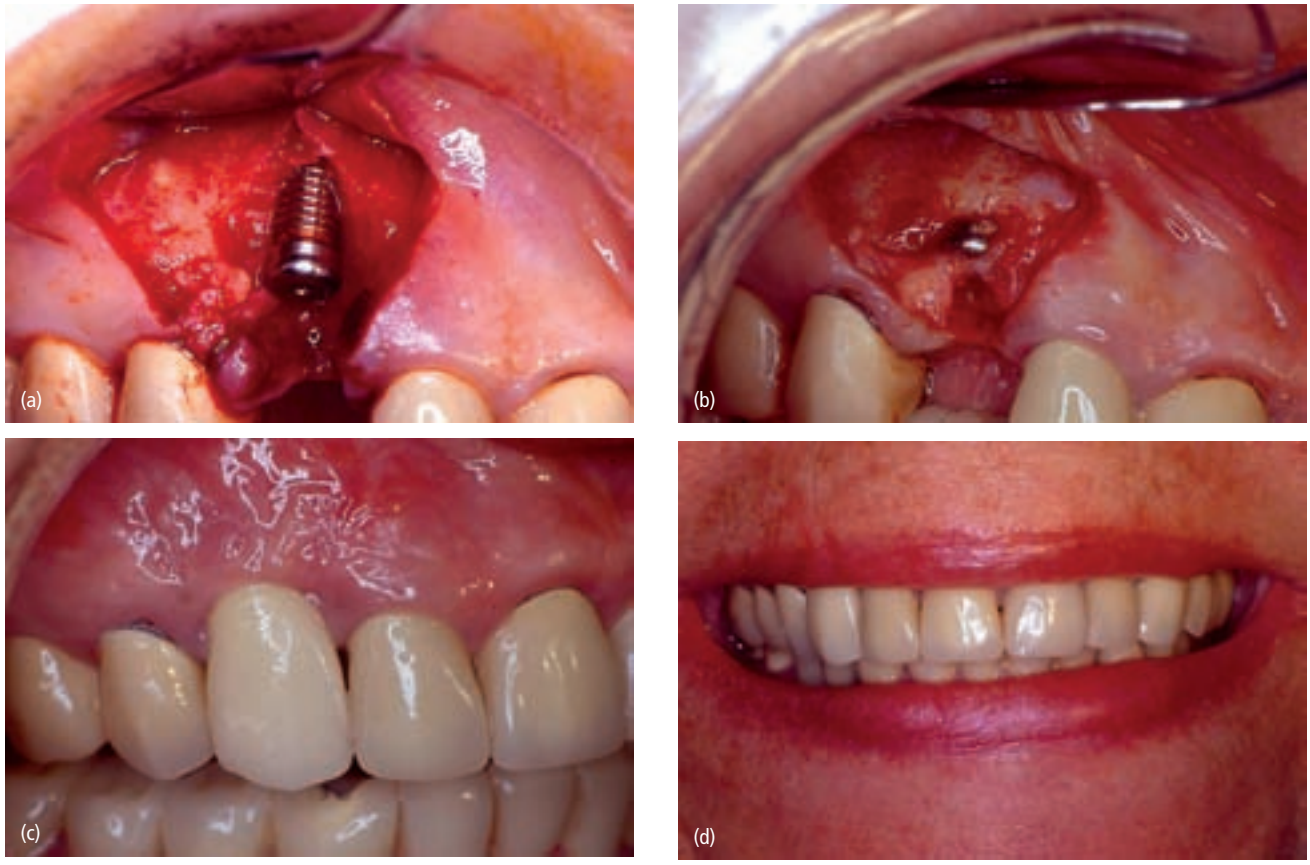


Fig. 18.3 (a) Immediate implant placement in an ideal restorative position demonstrating loss of the labial plate of bone which was augmented with an allograft and membrane at the time of implant placement. (b) After 6 months of healing the labial bone regeneration is evident. (c) Restoration 2 years after placement. (d) The patient exhibits a low smile line and does not show the gingival emergence of the restoration.

Fig. 18.4 Sharp pointed entry burs will enable the surgeon to initiate the osteotomy without sliding off the socket wall incline.

there are adequate bands of keratinized tissue. Advancement of flaps during healing leaves minimal keratinized tissue labial to the implant restoration. This usually requires reposition of the flaps that have previously been advanced or placement of a tissue graft to increase the dimension of tissue labially.

Gingival recession

Implant placement too far to the labial surface or the use of very wide implants which approach the labial bone leaving little "gap" space tend to increase the potential for gingival recession around implants placed with an IIP protocol. Adequate space labial to the implant is essential for long-term maintenance of the implant (Fig. 18.5a, b). Another problem concerns the unpredictable postsurgical gingival recession that may occur after extraction and IIP. This has been documented in several studies (25–29).

Implant failure

Implant failure can occur with the IIP protocol in native bone or previously regenerated ridges. Studies have demonstrated that the implant survival rate is similar with either an IIP or a delayed placement protocol (11). If an implant fails it can be replaced, either immediately by placing a wider implant or in a staged protocol after removal and ridge augmentation. Implant replacement, however, has recently been reported to have a lower implant survival rate (30).

Unacceptable esthetic outcomes

Even when the clinician follows the correct IIP protocol, the resulting restoration may still present with an unacceptable esthetic outcome (Fig. 18.6a–f) (31, 32) (see Chapter 12). Although the patient may have a low smile

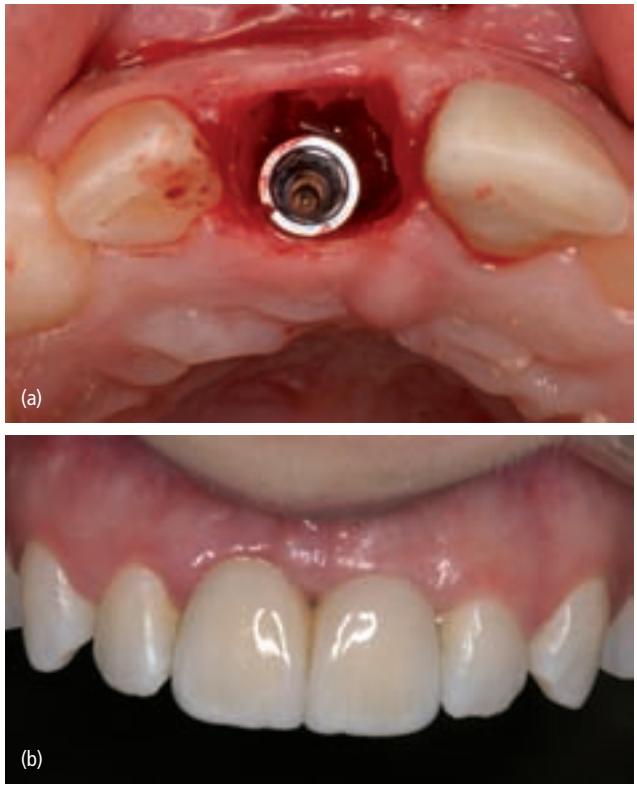
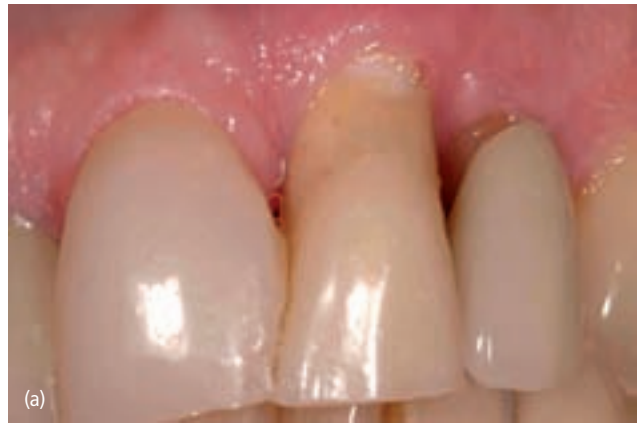


Fig. 18.5 (a) Note the palatal placement of the implant allowing regeneration and an increased thickness of bone on the labial which will help stabilize the tissue over the years. The adjacent central incisor was similarly extracted and an implant placed at the same visit. The areas were treated and provisionalized individually. (b) The final implant-supported restorations were fabricated on both incisors.

line and the gingival emergence may not show, the patient may still deem the result unesthetic. It is essential, therefore, before placement, to determine the patient's expectations. Those with high esthetic expectations should be considered for a staged approach for restoration of the ridge before implant placement. The limiting factor with regard to the potential for interdental papillae between a single implant and a natural tooth is the bone level on the adjacent teeth (see Chapter 11). In the case presented in Fig. 18.5, the bone between the central incisors was present. The bone level between the central and lateral incisors in Fig. 18.6 was diminished. Although in the postrestoration radiograph it appears that the implant was well positioned, the clinical results display a poor esthetic outcome (Fig. 18.6d). The fact that the patient had no problem functioning was of primary importance and, therefore, he accepted the esthetic result. However, from an ideal esthetic point of view, the restoration was not a success. The etiology of the esthetic problem in this case was partially due to the bone loss between the incisors. If the patient had been esthetically demanding, multiple procedures would have been necessary to create the proper architecture for the final restoration before implant placement. In addition, in this



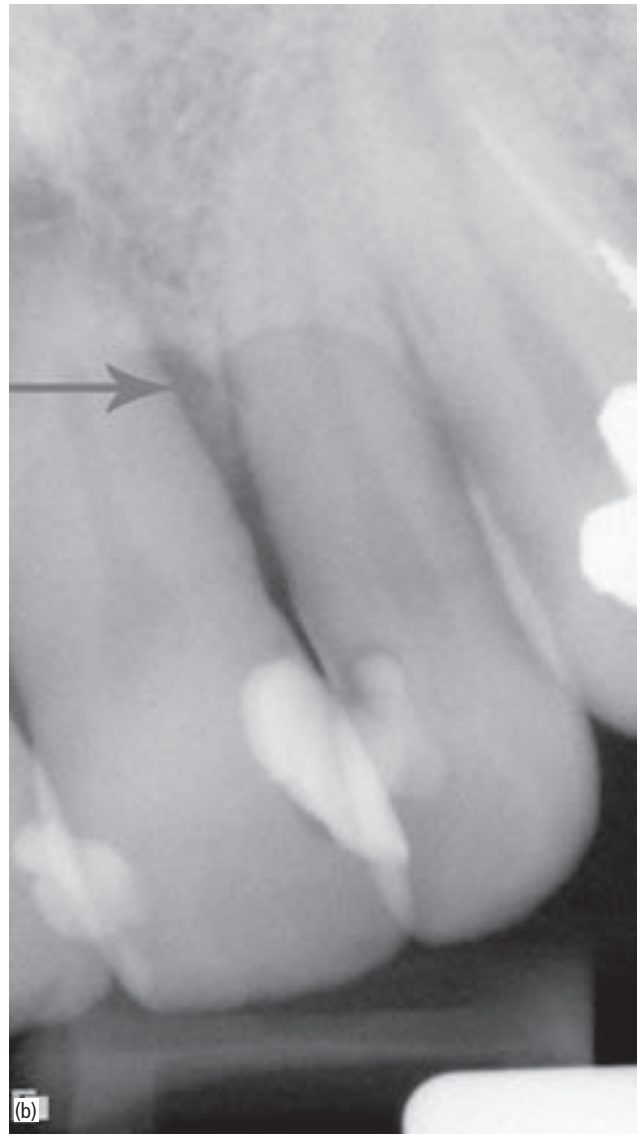
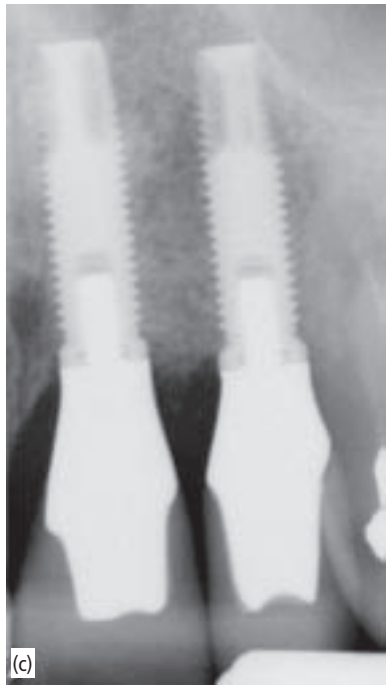
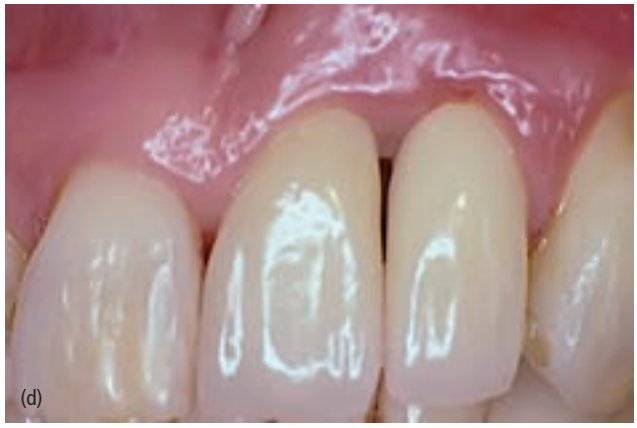
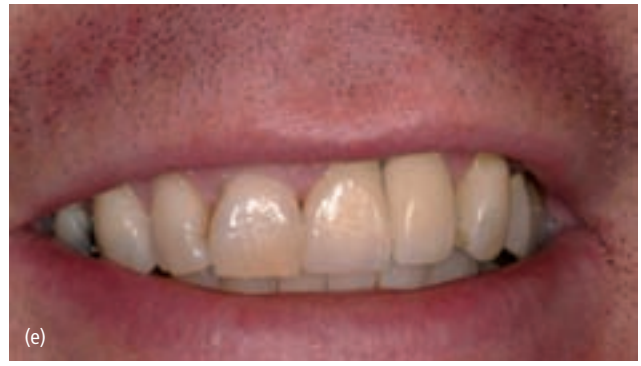


Fig. 18.6 (a) Clinical photograph demonstrating advanced periodontal disease between the left central and lateral incisors. (b) Radiograph demonstrating the extent of the bone loss around the teeth in (a).







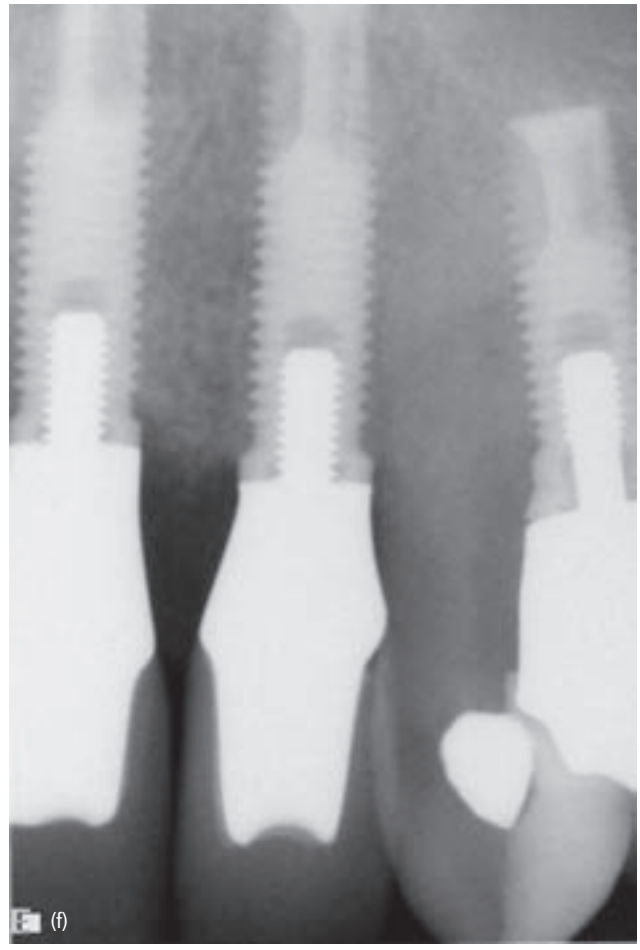


Fig. 18.6 ***(cont'd)*** (c) Radiograph of the restored implants. The position of the implants appears to be in good alignment. (d) Clinical photograph taken after restoration demonstrating the uneven gingival levels and deficient papillae associated with the left central and lateral implants compared to the adjacent teeth. (e) Unfortunately, the smile line exposes the tooth length discrepancy. (f) Despite the large amount of initial bone loss, the bone levels around the implants have been well maintained 5 years later.

case there existed the problem of obtaining a normal papilla height between two adjacent implants owing to the biology of the healing of these areas (see Chapter 12).

Immediate tooth replacement (non-occlusally loaded) at the time of extraction of the natural tooth

Implants placed at the time of extraction of the natural tooth which are in the esthetic zone are often a challenge to the clinician (see Chapters 8 and 11). As mentioned previously, it is essential that the implant be placed in the proper position related to the final restoration (Fig. 18.7a–f). Patients are usually not comfortable with removable provisionals such as partial dentures or Essix appliances. Acid etch retainers are difficult to manage because of the coordination necessary for removal and replacement. Fabrication of a provisional restoration allows the clinician to create an emergence profile and tissue support of the gingiva and papillae, which also help to maintain the contour of the natural tissue forms (Fig. 18.8a–c). The following are essential criteria for IIP and immediate provisionalization:

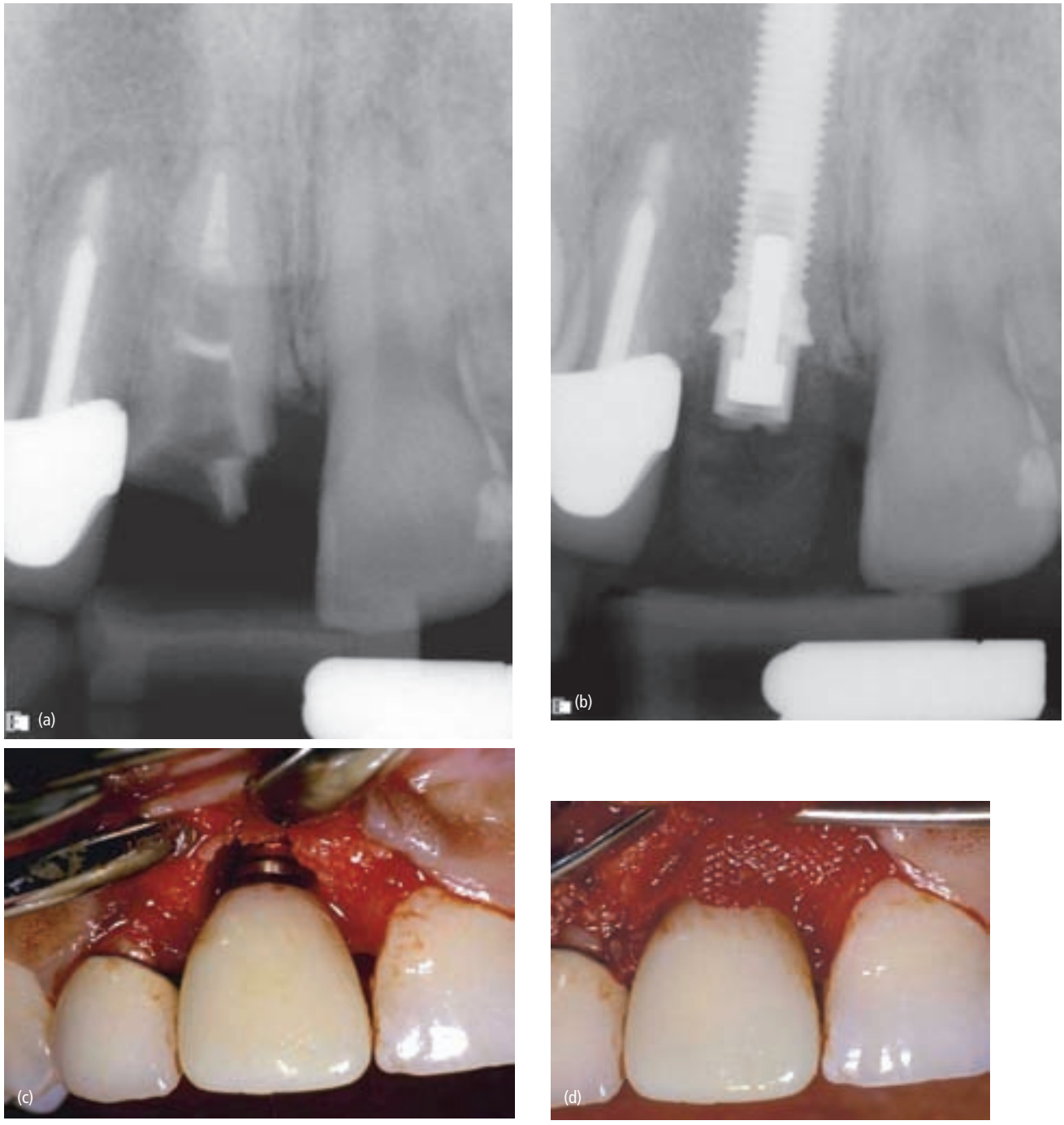
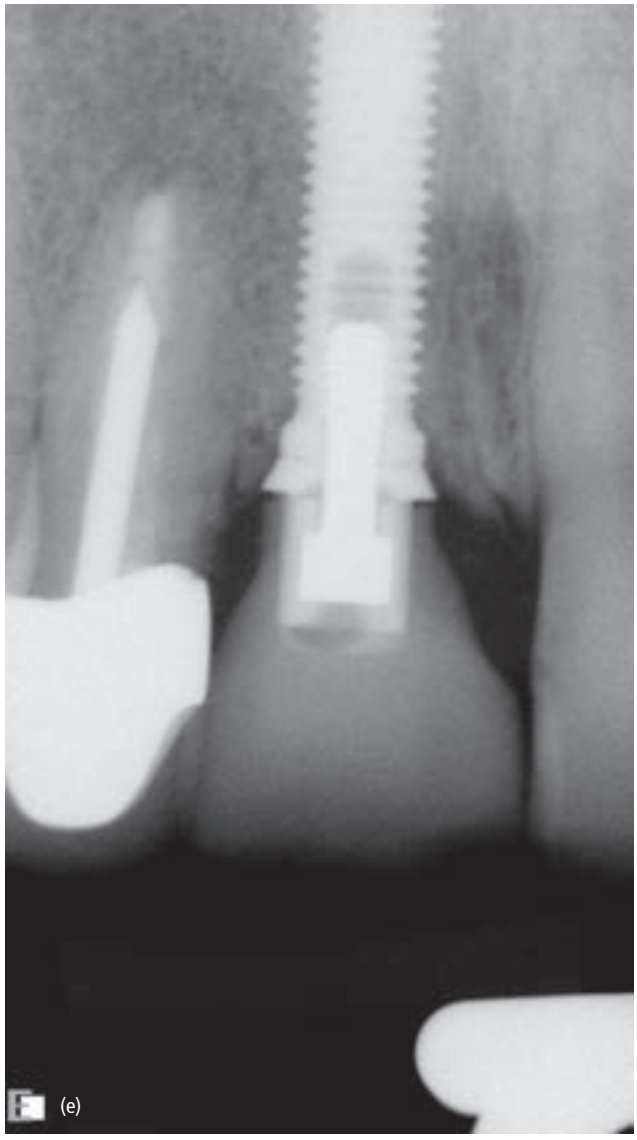


Fig. 18.7 (a) A root fracture of the maxillary right central incisor can be seen on this radiograph. (b) An immediate implant was placed after extraction and débridement of the socket, and an abutment was affixed at the time of surgery. (c) After fabrication of the provisional restoration (cemented with a strong cement to prevent loosening) a bone allograft was tightly packed between the implant and the alveolus. (d) A PG910 membrane was placed over the graft material external to the alveolar housing and contoured interproximally.

- removal of all infectious material from the socket
- adequate available tissue dimension
- initial stability of the implant
- patient cooperation with postsurgical maintenance.

It is essential that the clinician is able to avoid loading the immediate placed implants. The provisional restorations are usually single-tooth replacements in the anterior or maxillary bicuspids (a cuspid form is used to avoid an occlusal table) and are susceptible to macromotion from mastication. Food must be cut into small pieces and placed on the posterior dentition for mastication. Although casual contact is expected to occur, overload-



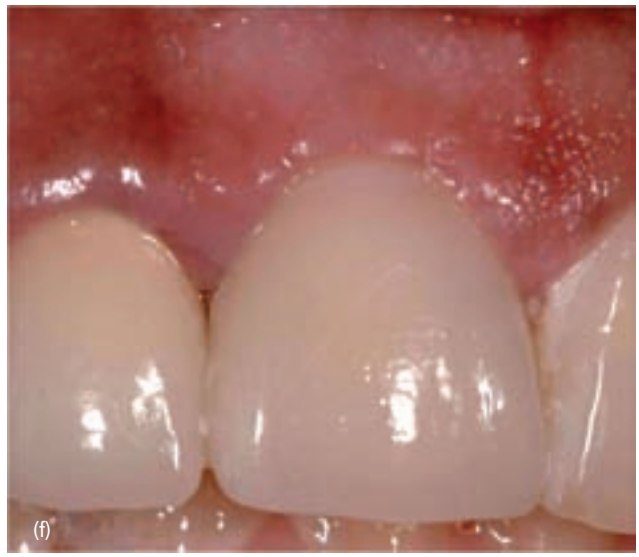


Fig. 18.7 ***(cont'd)*** (e) A radiograph taken 8 years after restoration demonstrates the stability of the bone. (f) The patient presented 8 years after restoration with slightly inflamed tissue, but clinically gingival heights are similar to those present immediately after restoration.

ing could lead to the failure of the implant. All of this must be explained to the patient and the patient must agree to comply with the postsurgical regimen. If the patient is not cooperative the IIP protocol and immediate provisionalization should not be the treatment option. For success of this protocol, the provisional restoration must be out of occlusion during maximum intercuspation as well as working movements.

Procedures to prevent failure using the immediate implant placement protocol with a non-loading provisional

The implant should be placed following the IIP protocol (Fig. 18.9a–e). An appropriate abutment should be chosen, placed on the implant, and torqued into place at the manufacturer's suggested force. A provisional restoration should be fabricated and cemented into place. All excess cement should be completely removed. Any required bone augmentation is then performed and an attempt is made to overbuild the site. The membrane is placed and the flap sutured without tension. Occlusion is rechecked to ensure that there is no loading.

Periodic examinations should be made to monitor the healing and to reinforce the no-mastication rule. If the clinician and patient follow this protocol results are usually highly predictable.

One additional advantage of these procedures is that the abutment is placed at the time of extraction and implant placement and often does not have to be changed. This has been shown to prevent marginal recession and bone loss around the implant (33).

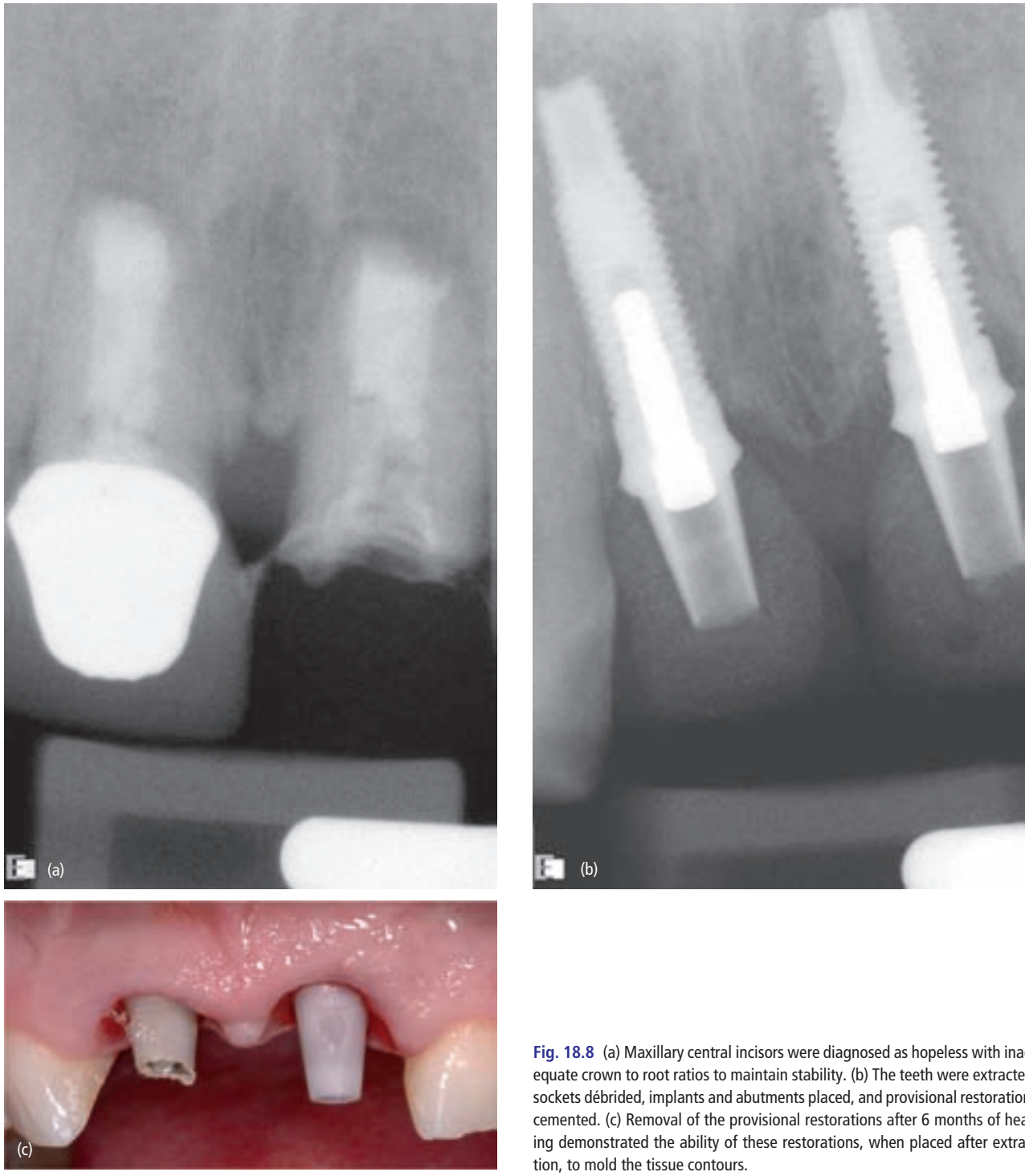


Fig. 18.8 (a) Maxillary central incisors were diagnosed as hopeless with inadequate crown to root ratios to maintain stability. (b) The teeth were extracted, sockets débrided, implants and abutments placed, and provisional restorations cemented. (c) Removal of the provisional restorations after 6 months of healing demonstrated the ability of these restorations, when placed after extraction, to mold the tissue contours.

Prevention

Achieving successful results with the IIP protocol requires strict adherence to proper procedures. The following criteria are essential for the success of IIP:

- Apical or lateral stabilization. The implant must be placed into enough native bone to attain primary stability. Dehiscence with thread exposure at the time of implant placement does not contraindicate this technique if initial stability can be obtained.
- All residual infection has to be removed. The socket must be examined after a thorough débridement which removes all residual fibers from the apical and lateral wall areas.
- The surgical and restorative clinicians must determine patient expectations, work with an ideal wax-

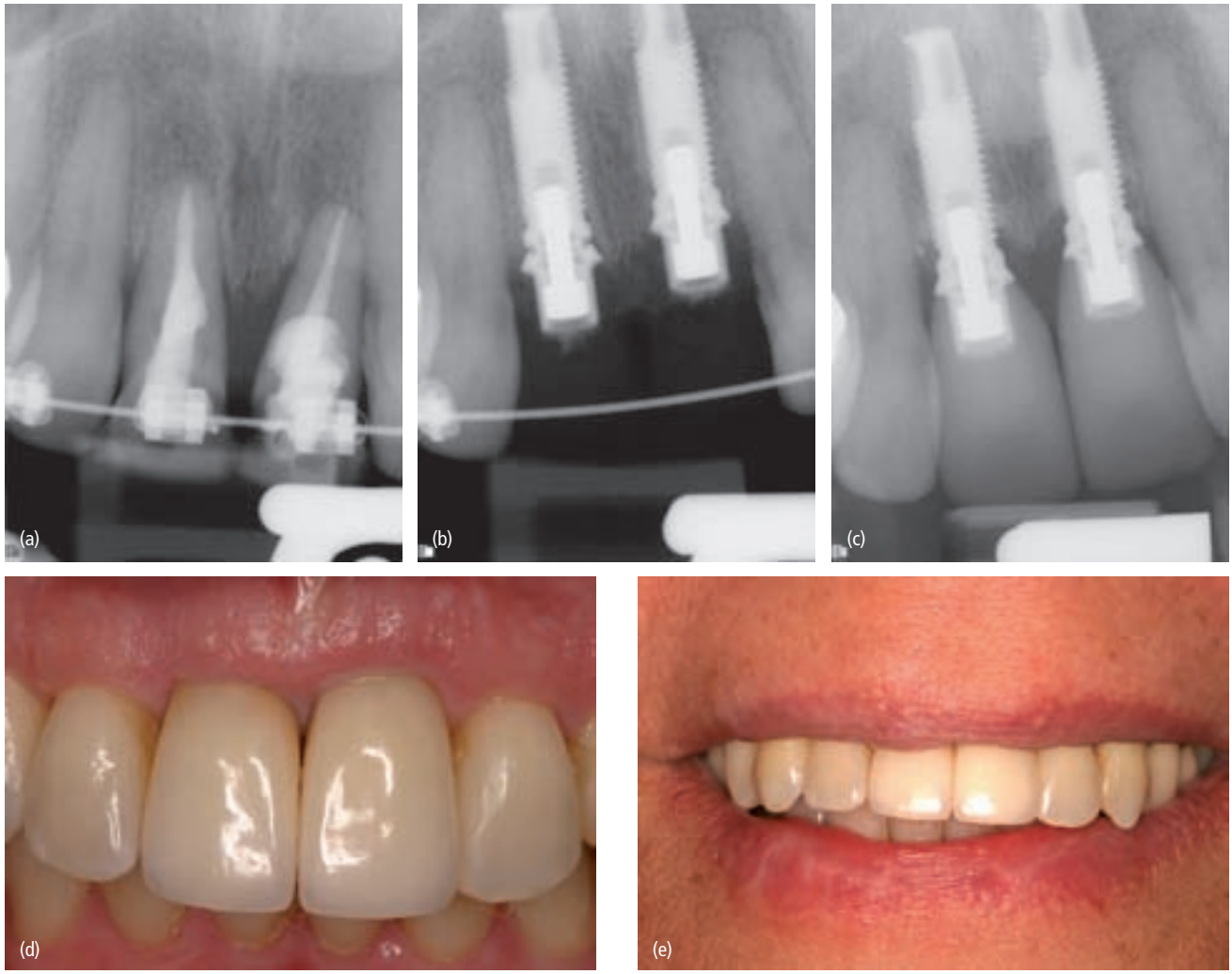


Fig. 18.9 (a) The maxillary right and left central incisors are failing. (b) The teeth were extracted, sockets thoroughly débrided, abutments placed, and the provisional restorations cemented in place without occlusal contact. Note the abutment is not fully seated on tooth no. 8. To avoid this complication a radiograph must be taken to verify seating of the abutment. In this case the abutment was reseated fully after the X-ray revealed the incomplete seat. (c) Radiograph taken 7 years after restoration showing crestal stability around the implants. (d) Clinical photograph showing gingival stability which followed the crestal stability. (e) The patient has a relatively low smile line.

up, and consider postsurgical bone resorption to determine whether the results will satisfy the patient's demands.

- The implant must be placed in an ideal position with precise surgical technique and consideration of the anatomy of the recipient site (34).
- The clinician must be comfortable with the technical aspects of the procedure.

The treatment protocol should be as follows.

Patients are given local infiltration anesthesia (no block anesthesia). Unless medically contraindicated, patients are infiltrated with lidocaine with 1:50 000 epinephrine (Abbott Laboratories, North Chicago, IL, USA). In cases where a non-epinephrine local anesthetic is required, mepivicaine 3% (Abbott Laboratories) should be used. Full-thickness flaps are reflected with minimal palatal elevation in the maxilla. Vertical incisions are used as necessary for visual access. The teeth to be removed should be extracted atraumatically without flap reflection whenever possible. Molars should be sectioned and roots removed separately. Roots should be removed by first creating a trough around the root with a very thin tapered diamond (Fig. 18.10a, b) (Komet USA LLC, Rock Hill, SC, USA). The clinician can then engage an elevator using minimum pressure to remove the root. Sockets of teeth with periapical or periodontal infections or with evidence of pathology (purulent exudate or granulomatous tissue) after extraction are not contraindicated for IIP (Fig. 18.11a–j). The infected material must be completely removed, and sockets thoroughly degranulated with curettes or burs and then re-examined. If all

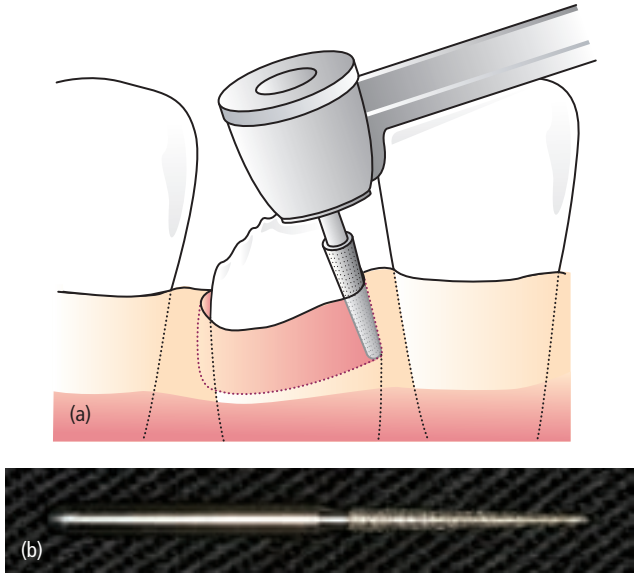
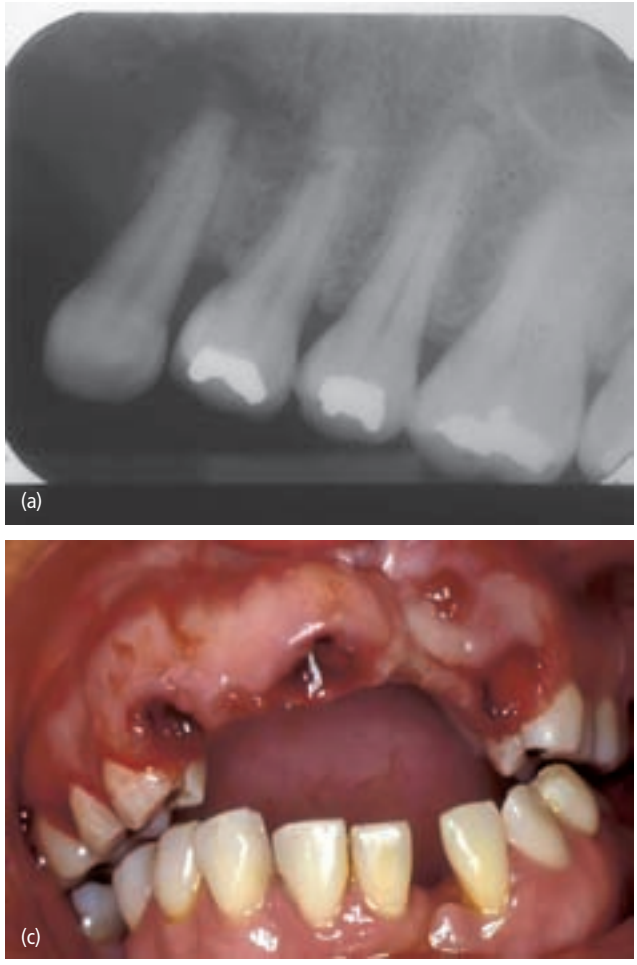


Fig. 18.10 (a) A tapered diamond bur is used to loosen the attachment of the tooth, making it easier for removal without the potential for bone loss. (b) A long thin diamond bur is used when root length is considerable.

remnants of fibers and soft tissue are removed from the sockets, the IIP can proceed. Standard drilling protocol is then followed according to the implant manufacturer's recommendations.

Implant placement varies by area and position of the remaining bone. Implants in the esthetic zone are placed slightly to the palatal. Implants in the bicuspid area in the maxilla should be placed to the palatal but apically through the remaining septum. In the mandibular bicuspid area implants should be placed in the center of the socket. In the maxillary and mandibular molar areas implants should be placed slightly to the mesial of the interradicular bone, most often using a wide implant, but not necessarily in contact with the buccal and lingual plates of bone (Fig. 18.12a–d). When sinus lifts are performed osteotomes can be used to complete the implant preparation if there is at least 3–4 mm of native bone present. If there is inadequate height of bone (< 3–4 mm) for osteotome preparation of the site and lateral window access to the sinus is necessary implants should not be placed concurrent with extraction but rather after graft



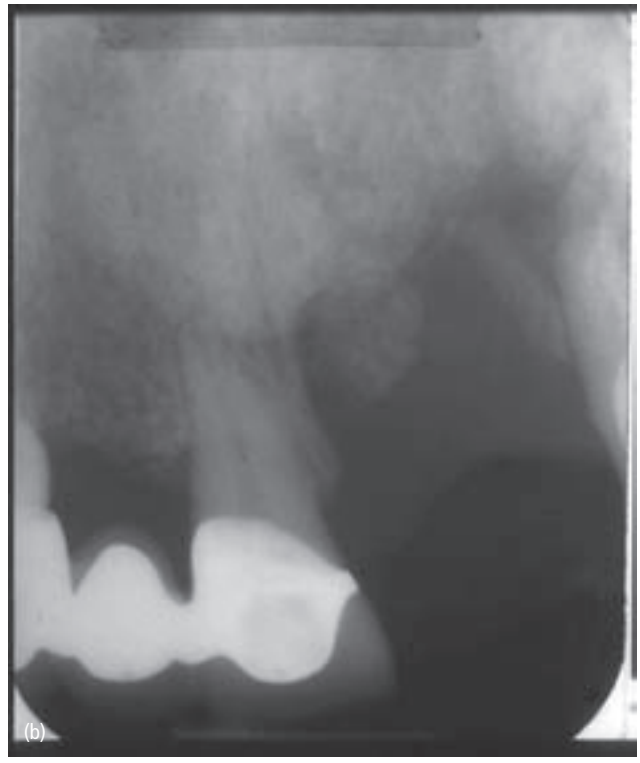
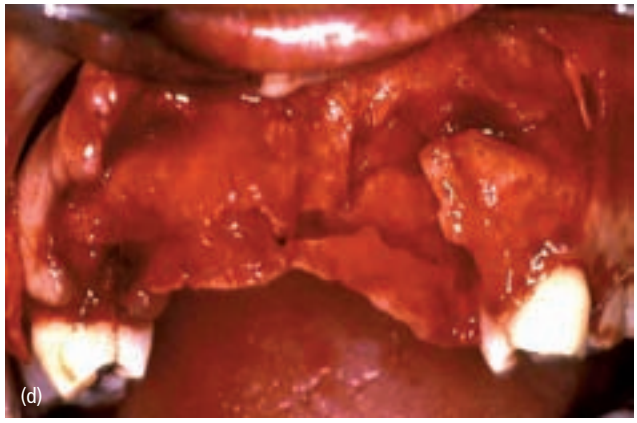
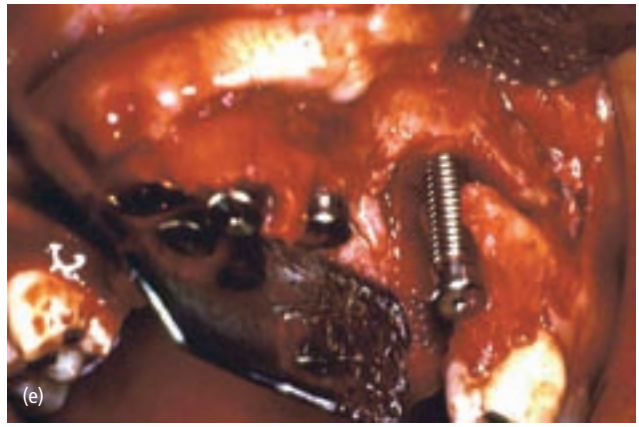
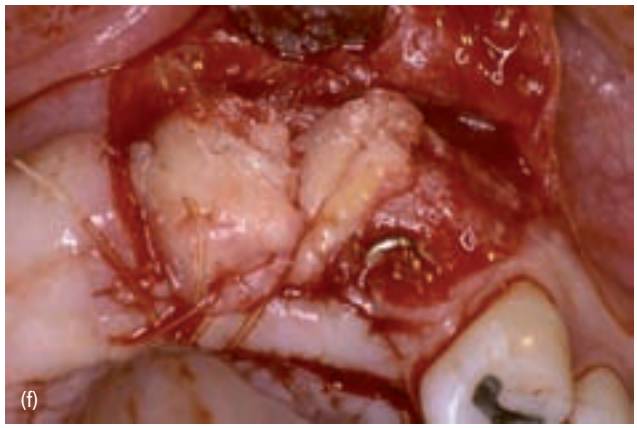
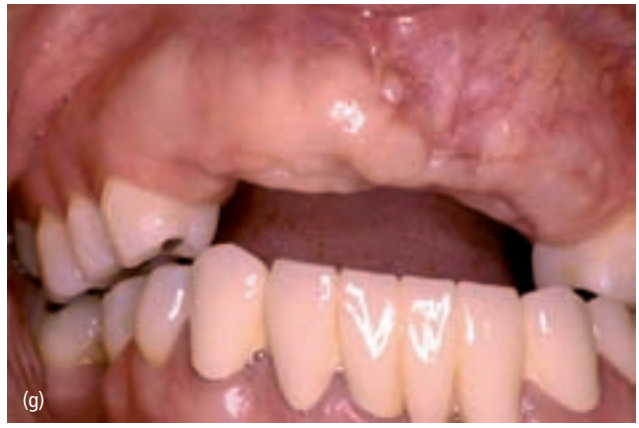


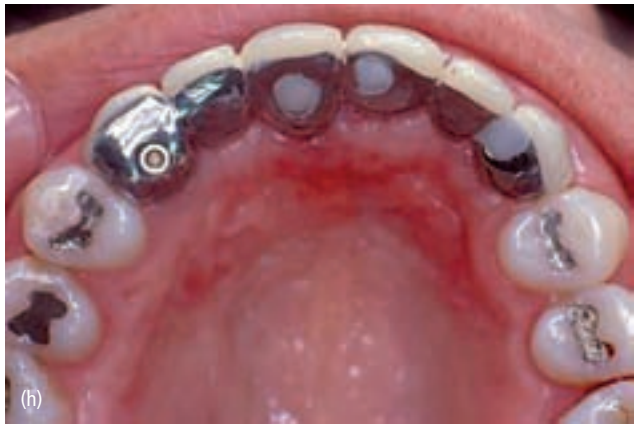
Fig. 18.11 (a, b) Radiographs showing the bone loss due to a traumatic accident which caused the displacement of the teeth. (c) A fistula is seen clinically facial to an infection in the canine region.

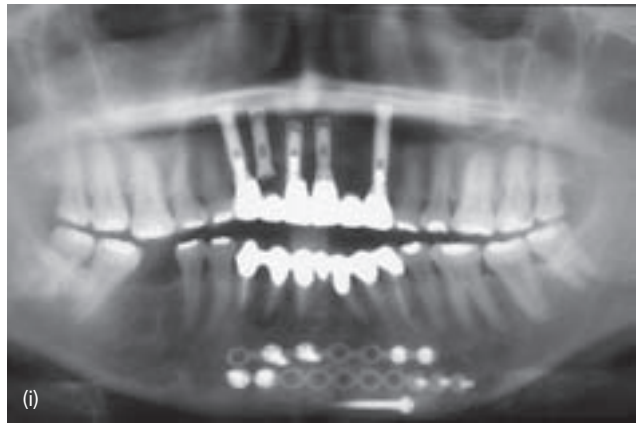












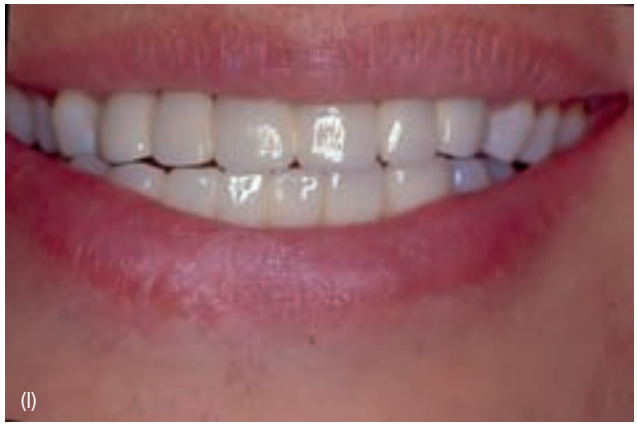


Fig. 18.11 ***(cont'd)*** (d) Following flap reflection and infection débridement a large bone defect remained. (e) Implants were placed in the ideal restorative position. Bone augmentation was performed to the height of the implants. (f) Augmentation of the left area was so successful that there was a discrepancy between the left and right sides. A connective tissue graft was placed to even out the ridge. Note the bone regeneration present around the previously exposed implant. (g) The ridge is even and ready for final restoration. (h) The final restoration was placed. (i) Panoramic radiograph demonstrating the final restoration. One implant was left unloaded. (j) The patient has been functioning well and has an excellent esthetic result.

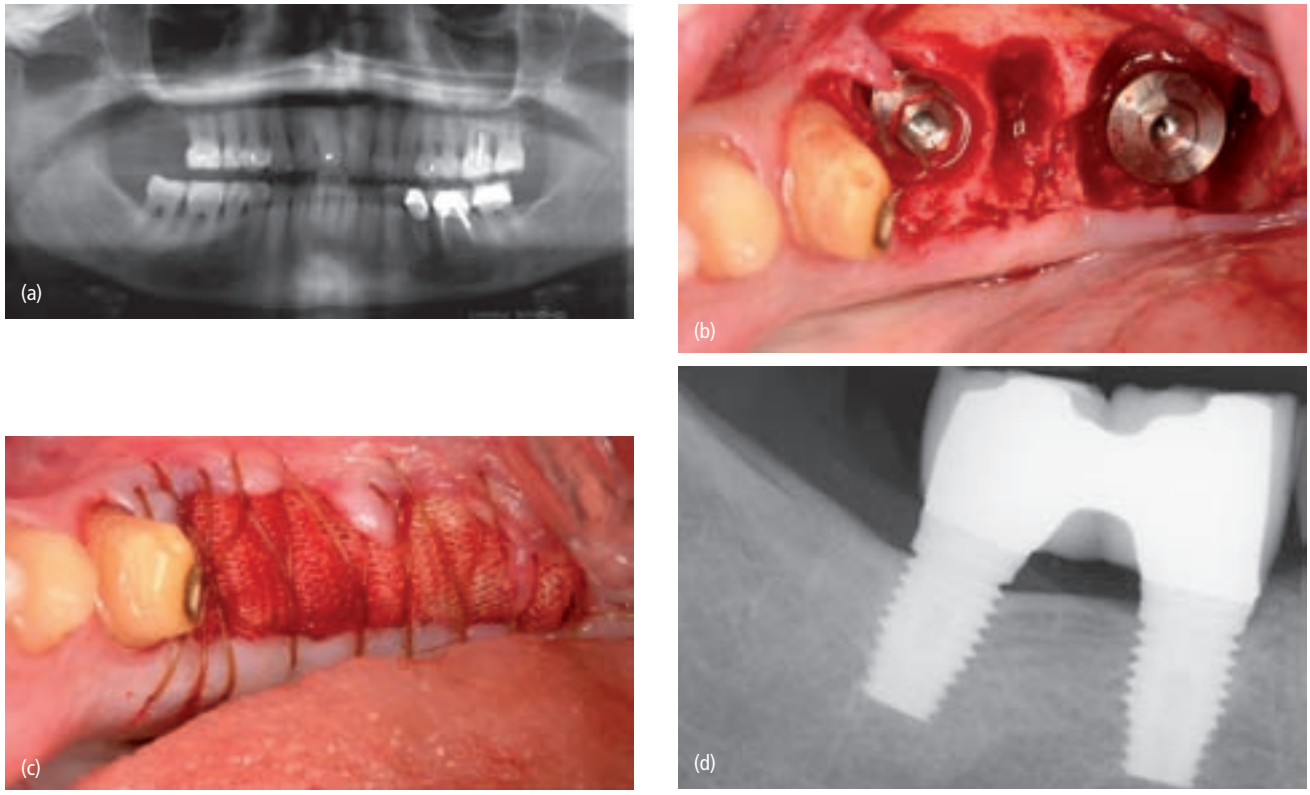


Fig. 18.12 (a) The mandibular right molars were hopeless and required removal. (b) Implants were placed into the existing sockets. Note the spaces around the implants which required bone grafting. (c) After firmly packing a mineralized allograft around the implants and into the sockets, a PG910 membrane was placed. No attempt was made to obtain primary closure of the tissues. (d) A radiograph taken 5 years after restoration demonstrated crestal stability.

healing with a delayed protocol. An appropriate length implant should be placed, leaving the platform 1–2 mm below the most coronal height of the remaining crest. Mineralized freeze-dried bone allograft (FDBA) (Miami Tissue Bank, University of Miami; Miami, FL, USA), should be tightly packed into the residual spaces around the implant. A periodontal probe or sterilized amalgam plugger, dedicated to this surgery, can be used to push the bone into narrow spaces. Bone grafts are used in all cases in which there is a residual space around the implant. After implant placement, cortical freeze-dried bone is tightly packed around the site and built up approximately to 120% of the intended final width and height. A PG910 Vicryl membrane (Ethicon; Johnson & Johnson, Somerville, NJ, USA) is custom contoured, extending 5–7 mm beyond the margins of the defects and tucked under the flaps both labially and palatally (lingually) without suturing. The flaps are closed using chromic 4-0 gut sutures. No attempt need be made to advance the flaps and cover the membrane (Fig. 18.12c). Patients should be premedicated with amoxicillin 500 mg four times a day (TEVA Pharmaceuticals USA, Sellersville, PA, USA) starting 2 days before the procedure, on the day of surgery, and continuing four times a day for 10 days postsurgery. Penicillin-sensitive patients are prescribed Zithromax (Pfizer, New York, NY, USA) before surgery and continuing 300 mg/day for 9 days. The patients are instructed to use 0.12% chlorhexidine gluconate (Peridex; Vila Pharmaceutical, Phoenix, AZ, USA) on a cotton tip to lightly clean any exposed membrane area three times a day until the membrane absorbs. Implants are allowed to heal for 3 months in the mandible and 6 months in the maxilla before second stage surgeries. In most cases final restoration should begin within 3–4 weeks of stage 2 surgery.

Treatment of complications

The best treatment for implant complications related to the IIP protocol is to follow the treatment protocol as outlined previously.

Specifically, to treat implant malposition, it is important to try to recognize this problem at the time of implant placement using a surgical guide based on an ideal wax-up and computed tomographic (CT) scans. If proper positioning is not attained at initial placement, removal of the implant and redirection, where possible, is indicated. If there is not enough bone to position the implant correctly, the implant should be removed and

the bone augmented with a GBR procedure, and after adequate healing a delayed placement protocol used (3–6 months).

If an implant integrates in a poor position either a prosthetic solution (see Chapter 9) or implant removal is indicated. Treatment for membrane exposure includes membrane removal (with non-absorbable membranes) or keeping the area clean as described previously until the membrane absorbs and the area heals.

Adequate bands of keratinized tissue can be created by flap positioning or connective tissue grafting at the time of or after implant placement. Postsurgical gingival recession can be avoided in many cases by proper implant positioning and patient selection (gingival recession is less likely in patients with a thick biotype). Following implant integration and restoration, connective tissue grafts can be used to treat gingival recession (see Chapter 25).

Finally, as mentioned earlier, poor esthetic outcomes are at times subjective and subject to patient expectations (see Chapter 3). A number of procedures can be performed to enhance esthetic outcomes after final restoration (see Chapter 25). However, these procedures are costly, include more surgery and time, often require multiple surgeries, and are not always predictable. Implant removal is also a treatment option, but it entails the disadvantages listed above. The IIP protocol is technique sensitive and should be avoided in the esthetic zone by clinicians with limited experience with this procedure.

Take-home hints

- Before tooth extraction and IIP, a thorough medical and habit history should be obtained and patient expectations and compliance determined.
- Case selection is critical. Patients who have no healing problems, who have thick biotypes, with adequate bone and soft tissue, and who are compliant, pose the least risk for complications.
- Follow the strict IIP protocol for implant placement and immediate or delayed restoration.
- Extract the tooth atraumatically using a flapless approach whenever possible, preserving the papillae and socket bone.
- Thoroughly débride the socket.
- Place the implant in an ideal three-dimensional restorative position.
- Be familiar with GBR procedures as well as soft-tissue grafting procedures to cover exposed threads.
- Know what to do when things go wrong.

References

1. Adell R, Lekholm U, Rockler B, Brånemark P-I. A 15-year study of osseointegrated implant in the treatment of the edentulous jaw. *Int J Oral Surg* 1981; **10**: 387–416.
2. Brånemark P-I, Zarb G, Albrektsson T. *Tissue-integrated prostheses: osseointegration in clinical dentistry*. Chicago, IL: Quintessence, 1985.
3. Misch CM. Autogenous bone grafting for dental implant. In: Fonseca RJ, Turvey TA, Marciani RD, eds. *Oral and maxillofacial surgery*, Vol. 1, 2nd edn. Philadelphia, PA: WB Saunders Co., 2008: 344–70.
4. Hammerle CH, Jung RE. Bone augmentation by means of barrier membranes. *Periodontol 2000* 2003; **33**: 36–53.
5. Chiapasco M, Bursati R, Ronchi P. Le Fort I osteotomy with interpositional bone grafts and delayed oral implants for the rehabilitation of extremely atrophical maxillae: a 1–9 year clinical follow-up study on humans. *Clin Oral Implants Res* 2007; **18**: 74–85.
6. Jensen O, Cockrell R, Kuhlke L, Reed C. Anterior maxillary alveolar distraction osteogenesis: a prospective 5-year clinical study. *Int J Oral Maxillofac Implants* 2002; **17**: 52–68.
7. Schulte W, Kleineikenscheidt H, Linder K, Schareyka R. The Tubingen immediate implant in clinical studies. *Dtsch Zahnarztl* 1978; **5**: 348–59.
8. Lazzara RJ. Immediate implant placement into extraction sites. Surgical and restorative advantages. *Int J Periodontics Restorative Dent* 1989; **9**: 333–9.
9. Schwartz-Arad D, Chaushu G. The ways and wherefores of immediate placement of implant placement of implants into fresh extraction sites: a literature review. *J Periodontol* 1997; **68**: 915–23.
10. Chen ST, Wilson TG Jr, Hammerle CF. Immediate or early placement of implants following tooth extraction: review of biologic basis, clinical procedures, and outcomes. Consensus statement. *Int J Oral Maxillofac Implants* 2004; **19** (Suppl): 12–28.
11. Mayfield L. Immediate, delayed and late submerged and transmucosal implants. In: Lang NP, Karring T, Lindhe J, eds. *Proceedings of the Third European Workshop on Periodontology Implant Dentistry*. Berlin: Quintessence, 1999: 520–34.
12. Siegenthaler DW, Jung RE, Holderegger C, Roos M, Hammerle CHF. Replacement of teeth exhibiting periapical pathology by immediate implants. *Clin Oral Implants Res* 2007; **18**: 727–37.
13. Schwartz-Arad D, Grossman Y, Chaushu G. The clinical effectiveness of implants placed immediately into fresh extraction sites of molar teeth. *J Periodontol* 2000; **71**: 839–44.
14. Gelb D. Immediate implant surgery: 3-year retrospective evaluation of 50 consecutive cases. *Int J Oral Maxillofac Implants* 1993; **3**: 389–99.
15. Mensdorff-Pouilly N, Haas R, Mallath G, Watzed G. The immediate implant: a retrospective study comparing the different types of immediate implantation. *Int J Oral Maxillofac Implants* 1994; **9**: 571–8.

16. Becker BE, Becker W, Ricci A, Geurs N. A prospective clinical trial of endosseous screw-shaped implants placed at the time of tooth extraction without augmentation. *J Periodontol* 1998; **69**: 920–6.
17. Grunder U, Polizzi F, Goene R, Hatano N, Henry P, Jackson WJ, *et al.* A 3-year prospective multi-center follow-up report on the immediate and delayed-immediate placement of implants. *Int J Oral Maxillofac Implants* 199; **14**: 210–16.
18. Schwartz-Arad D, Gulayen N, Chaushu G. Immediate versus non-immediate implantation for full arch fixed reconstruction following extraction of all residual teeth: a retrospective comparative study. *J Periodontol* 2000; **71**: 923–8.
19. Gomez-Roman G, Kruppenbacker M, Weber H, Schulte W. Immediate post extraction implant placement with not-analog stepped implants: surgical procedure and statistical outcome after 6 years. *Int J Oral Maxillofac Implants* 2001; **16**: 503–13.
20. Wagenberg BD, Ginsberg TR. Immediate implant placement on removal of the natural tooth. Retrospective analysis of 1081 implants. *Compend Contin Educ Dent* 2001; **22**: 399–410.
21. Prosper L, Gherlome EF, Redalle S, Quaranja M. Four-year-follow up at large diameter implants placed in fresh extraction sockets using a resorbable membrane or a resorbable alloplastic material. *Int J Oral Maxillofac Implants* 2009; **18**: 854–6.
22. Covani U, Crespi R, Cornelini R, Barone A. Immediate implant supporting single crown restoration. A 2-year prospective study. *J Periodontol* 2004; **75**: 982–8.
23. Bianchi AR, San Filippo F. Single tooth replacement by immediate implant and connective tissue graft. A 1–9 year clinical evaluation. *Clin Oral Implants Res* 2004; **15**: 269–77.
24. Wagenebrg B, Froum SJ. A retrospective study of 1925 consecutively placed immediate implants from 1988–2004. *Int J Oral Maxillofac Implants* 2006; **21**: 71–80.
25. Chen ST, Darby IB, Adams GG, Reynolds EC. A prospective clinical study of bone augmentation techniques at immediate implants. *Clin Oral Implants Res* 2005; **16**: 176–84.
26. Lindenboom JA, Tjiook Y, Kroon FH. Immediate placement of implants in periapical infected sites: a prospective randomized study in 50 patients. *Oral Surg Oral Med Oral Pathol Endodontol* 2006; **101**: 705–10.
27. Chen ST, Darby IB, Reynolds EC. A prospective clinical study of non-submerged immediate implants: clinical outcomes and esthetic results. *Clin Oral Implants Res* 2007; **18**: 552–62.
28. Kan JYK, Rungcharassaeng K, Sclar A, Lozada JL. Effects of the facial osseous defect morphology on gingival dynamics after immediate tooth replacement and guided bone regeneration: 1-year results. *J Oral Maxillofac Surg* 2007; **65**: 13–19.
29. Chen ST, Darby I, Reynolds EC. Immediate implant placement post-extraction without flap elevation: a case series. *J Periodontol* 2009; **80**: 163–72.
30. Grossman Y, Levin L. Success and survival of single dental implants placed in sites of previously failed implants. *J Periodontol* 2007; **78**: 1670–4.
31. Evans CJD, Chen ST. Esthetic outcomes of immediate implant placements. *Clin Oral Implants Res* 2008; **19**: 73–80.
32. Chen ST, Buser D. Clinical and esthetic outcomes of implants placed in post-extraction sites. *Int J Oral Maxillofac Implants* 2009; **24** (Suppl): 186–217.
33. Abrahamsson I, Berglundh T, Lindhe J. The mucosal barrier following abutment dis/reconnection. An experimental study in dogs. *J Clin Periodontol* 1997; **24**: 568–72.
34. Buser D, Martin W, Belser UC. Optimizing esthetics for implant restorations in the anterior maxilla: anatomic and surgical considerations. *Int J Oral Maxillofac Implants* 2004; **19** (Suppl): 43–61.

Chapter 19

Complications associated with flapless surgery

Thomas G. Wilson, Jr. DDS

Introduction

Correct placement of dental implants is challenging. Lack of surgical experience (inexperience in dealing with soft-tissue incisions, flap reflection, and surgical sequelae such as bleeding, swelling, and pain) and the potential for complications have led to hesitancy on the part of some dentists to place implants. In an effort to reduce the surgical complexity of implant placement, minimally invasive surgical procedures have been suggested. These procedures are often termed "flapless" surgery (1–3). However, these procedures often require more experience and skill than those necessary for conventional implant placement. The purpose of this chapter is to explore these minimally invasive procedures, define their meaning, identify appropriate clinical indications, and discuss the etiology, prevention, and treatment of complications when they arise as sequelae to this approach.

Definition of flapless surgery

A flap is soft tissue (epithelium and connective tissue covering bone) that is raised or elevated for surgical access. Flapless surgery is defined as implant placement performed without the elevation of a flap (4). This may be accomplished by drilling into the alveolar bone through intact tissue or drilling following a punch removal of soft tissue over the site of the implant osteotomy. In this chapter, immediate implant placement after tooth extraction will not be considered a flapless procedure.

Goals of therapy

One of the goals of therapy is to have dental implants surrounded on all sides by healthy, functioning bone. For the purposes of this chapter, it will be assumed that an adequate band of keratinized gingiva at the surgical site will result in fewer clinical and maintenance problems for the implant patient. Few clinicians would question the first goal in terms of its relevance for long-term clinical survival of implants. The second assumption is more controversial. However, many experienced clinicians feel that an adequate band of keratinized gingiva surrounding the implant will lead to fewer clinical problems and a diminished amount of bone loss seen radiographically over time. This opinion is based on clinical experience as well as published data (5–8).

Several possible problems can occur when using a flapless approach. These include:

- improper implant placement in relation to the final proposed restoration
- damage to contiguous structures
- destruction of keratinized tissue needed to stabilize soft tissues around the implant.

Etiology of complications

Complications involving flapless surgery can arise from inadequate clinical evaluation of potential implant sites. These sites should have adequate space for implant placement as well as for an appropriate final restoration. In addition, it is recommended that the site has enough keratinized tissue to allow placement of the implant that will result in an adequate band of this tissue surrounding the implant after healing. It is the author's opinion that a minimum of 1 mm of keratinized tissue around an implant restoration is needed to minimize clinical problems such as movement of the soft tissue during function.

A thick band of keratinized tissue is especially important on the facial aspect of implants placed in the esthetic zone to reduce the risk of gingival recession.

Two-dimensional radiographs (periapical and panoramic) are rarely adequate to evaluate a site for flapless implant placement. It is therefore highly recommended that conventional computed tomography (CT), cone beam computed tomography (CBCT), or lateral tomography be used as diagnostic aids during the planning and placement phases.

An additional problem with flapless implant placement is the operator's inability to visualize the relationship of the head of the implant to the alveolar bone. This often results in implants placed too far coronally or apically, thus compromising the restoration.

Prevention of complications

Correct placement of an implant and correct positioning of the final restoration in relation to contiguous structures are challenging even for the most experienced implant dentists. It is therefore recommended that a device be used to guide the drills during the osteotomy.

Traditional surgical templates can be useful. These templates are generated from a wax-up of the final proposed restoration. A radiographic guide, usually impregnated with a radiopaque material such as barium, is then constructed to relate the radiographic positions correctly to the final proposed prosthesis (Fig. 19.1) This guide is placed in the mouth when radiographs are exposed (9). Corrections based on the radiographs are then made and a surgical template is fabricated. This surgical template is used to guide drills during the osteotomy. This approach provides a basic surgical guide but is generally less accurate than templates constructed using digital planning programs (Figs 19.2–19.6).

Planning

Computer-assisted implant planning can facilitate proper implant placement, regardless of surgical technique. To use these programs, the dentist utilizes the CT or CBCT, which is formatted to interact with specially designed computer software. Using these programs, digitized simulated implants (avatars) of multiple design, sizes, and shapes can be placed in the desired implant positions. To take maximum advantage of these programs CBCT scans that are exposed with radiopaque materials representing the proposed final restoration and the prosthetic abutment relationship to that restoration are recommended. A common approach involves fabrication of a mock-up of the proposed final restoration from 85% acrylic and 15% barium powder. This mock-up is positioned on the study cast of the patient's arch in optimal relation to the final proposed restoration and fixed in place using vacuum-formed material (10).

A 3-mm diameter opening is made in the mock-up of the restoration indicating the desired relation of the abutment and osteotomy to the final prosthesis. The resulting tomogram is then placed into the computerized planning program.

Digital implant avatars which simulate implant position are then manipulated into the optimal position in relation to contiguous structures and the proposed final restorations (Fig. 19.7). This digital plan can be used in two ways:

- A hard copy of the plan can to be taken into the operatory during implant placement as a reference guide for implant size and position.

Fig. 19.1 Vacuum-formed template with barium-impregnated representations of the proposed final restorations. The openings are the proposed pathways of the implant drills. It is worn by the patient when radiographs are taken. Outlines of the proposed drill path and its relation to available bone can be seen and used during the planning process.

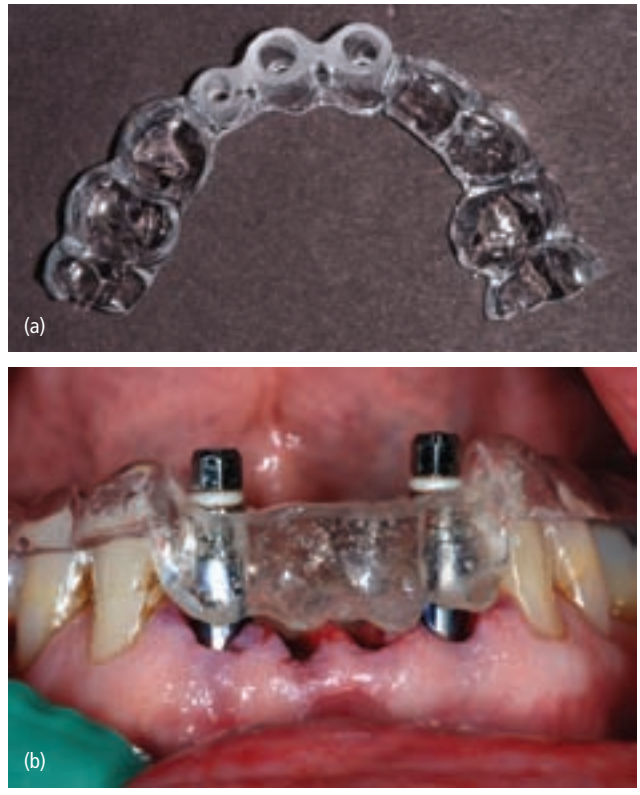
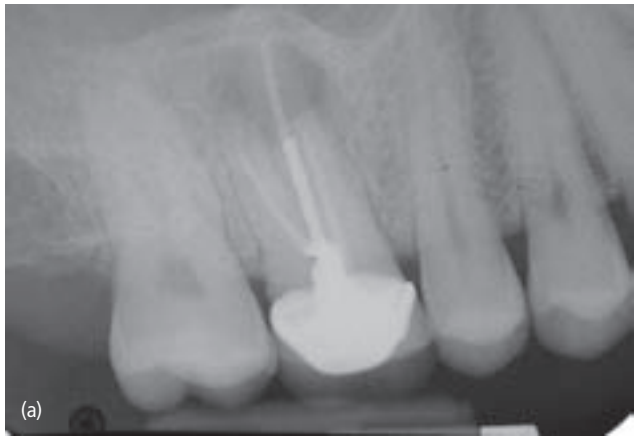
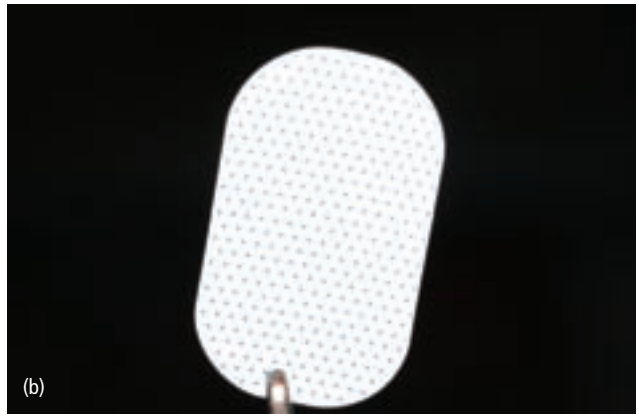
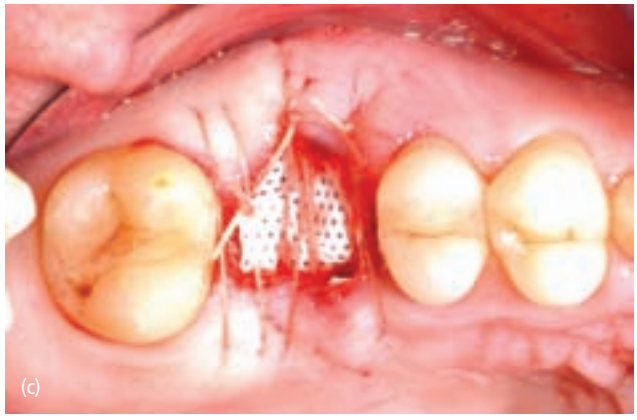
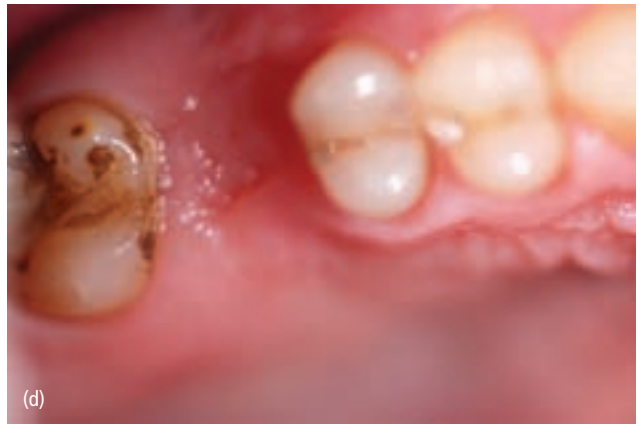


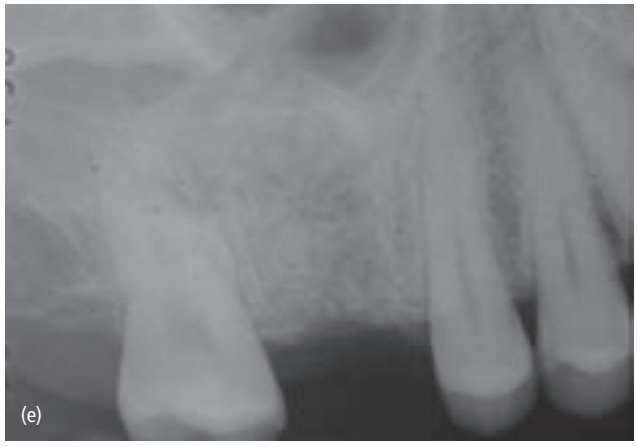
Fig. 19.2 (a) Traditional surgical template containing the diameter of the final proposed implant twist drill. It is fabricated to provide stability of these drills. The position of the opening is related to the final implant prosthesis by first performing a wax-up of the proposed final crown then relating the opening to the desired position of the implant in relation to the crown (9). (b) A traditional surgical template seen following implant placement.

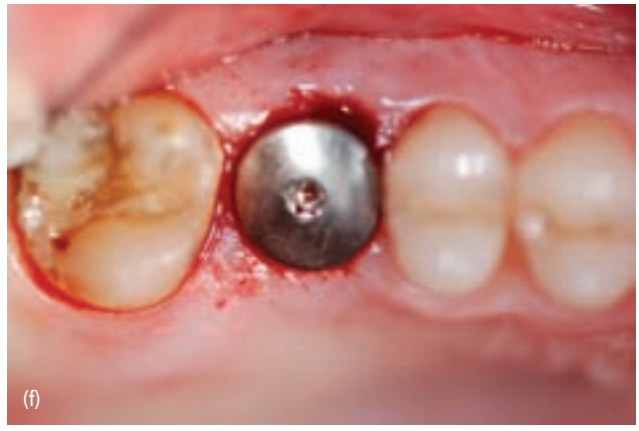












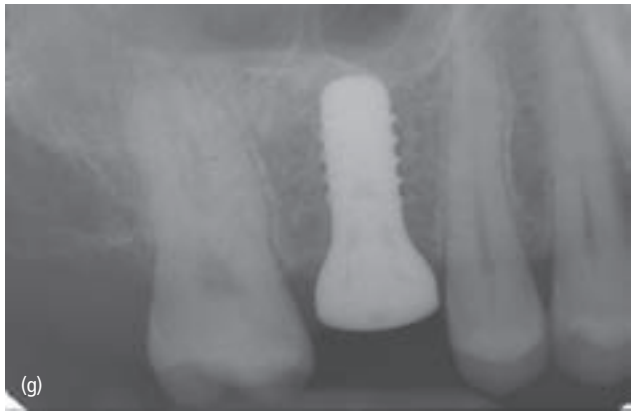


Fig. 19.3 (a) Fracture of an endodontically treated maxillary first molar necessitated its removal. Immediate implant placement was not used because of the inability to stabilize the implant following tooth extraction. (b, c) Socket preservation was performed with human freeze-dried decalcified bone and the socket was covered with a dense PTFE membrane without advancing the flaps for primary closure. (d) This approach resulted in a significant increase in the amount of keratinized gingiva compared to approaches using a palatally positioned full-thickness mucoperiosteal flap. (e) The resulting implant site had ample bone and keratinized gingiva for implant placement using a traditional surgical template. (f) This allowed the implant to be placed without raising a flap. (g) The implant position is as planned, as seen in the radiograph.

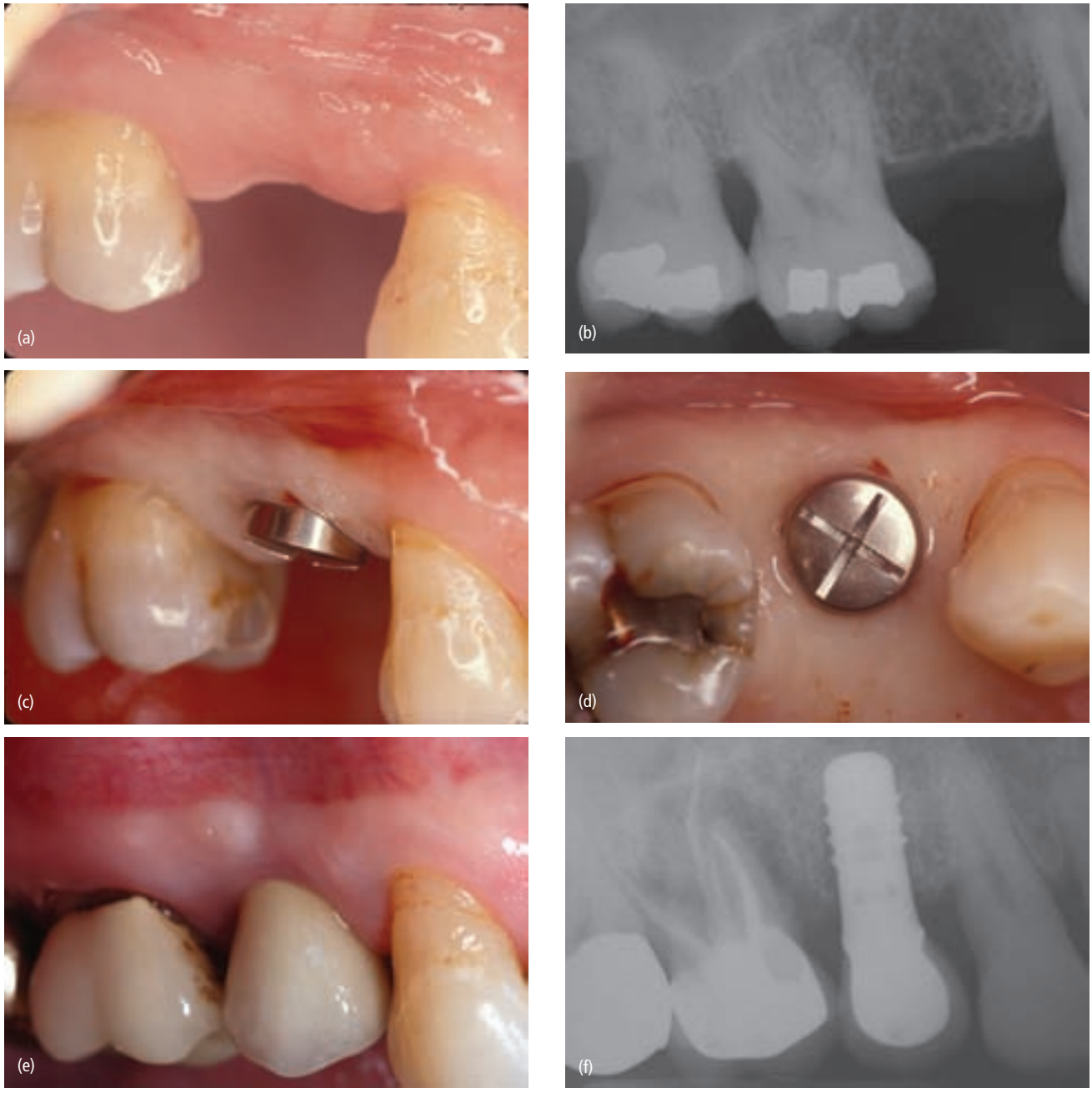


Fig. 19.4 (a–d) Adequate bone and keratinized gingiva in the proposed implant site allowed placement without raising flaps in the maxillary bicuspid. (e, f) The area 8 years after implant placement where the first molar was scheduled for removal.

- The plan can be used for computer-aided implant placement (guidance or navigation) (Table 19.1).

When using a flapless approach, drilling accuracy is extremely important. A hard copy of the implant avatars offers little or no positive guidance to the actual surgical direction of the osteotomy drills.

A recent study has shown that when no surgical guide is used, even when a CBCT was available, flapless procedures resulted in perforation of the bony plates more

Table 19.1 Computer-aided implant placement

- Computer-aided navigation (4) computer system for intraoperative navigation, which provides the surgeon with current positions of the instruments and operation site on a three-dimensional reconstructed image of the patient that is displayed on a monitor in the operating room. The system aims to transfer preoperative planning on radiographs or computed tomography scans to the patient, in real time, and independently of the position of the patient's head.
- Computer-assisted manufacture surgical guidance (4). Computed tomogram imaging augmented by implant placement planning to fabricate a surgical template for osteotomy localization during surgery.

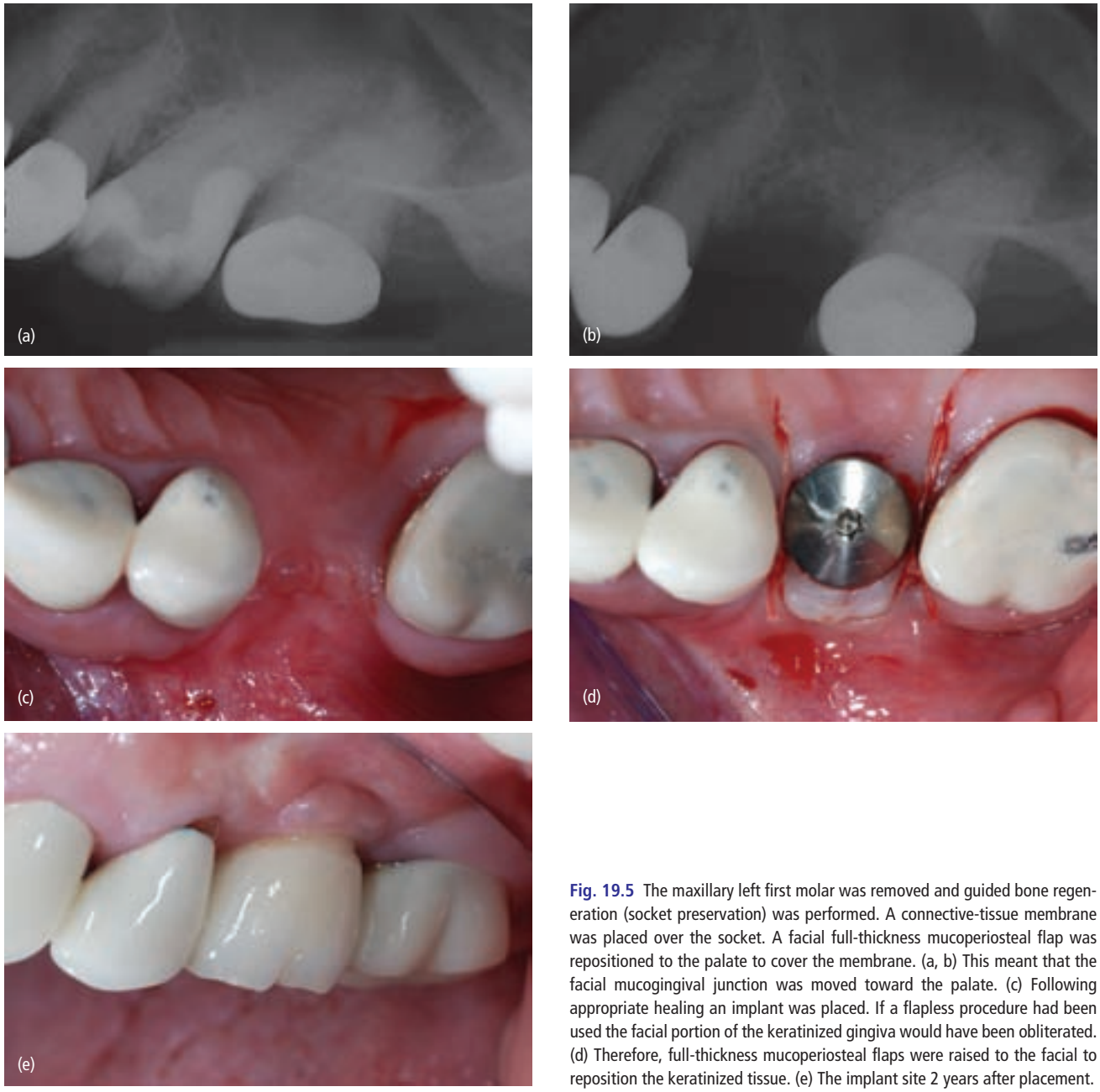


Fig. 19.5 The maxillary left first molar was removed and guided bone regeneration (socket preservation) was performed. A connective-tissue membrane was placed over the socket. A facial full-thickness mucoperiosteal flap was repositioned to the palate to cover the membrane. (a, b) This meant that the facial mucogingival junction was moved toward the palate. (c) Following appropriate healing an implant was placed. If a flapless procedure had been used the facial portion of the keratinized gingiva would have been obliterated. (d) Therefore, full-thickness mucoperiosteal flaps were raised to the facial to reposition the keratinized tissue. (e) The implant site 2 years after placement.

than 60% of the time. No relation was found to the experience of the operator (11). It has also been suggested that flapless surgery was one of the causes of implant failure (12, 13). This information suggests that flapless procedures without additional surgical guides may result in compromised clinical outcomes.

Therefore, it is recommended that some type of guide be used to direct the surgical drills during flapless procedures. The more compromised the potential implant site, the more accuracy of position is necessary. Two forms of digitally aided placement are currently available: computer-assisted manufactured surgical guidance (hereafter called guidance) (e.g. Materialize Dental NV, Leuven, Belgium) and computer-aided navigation (hereafter called navigation) (e.g. Image Navigation, Jerusalem, Israel).

Guidance

Following digital planning as described above, surgical templates are ordered. In their usual form, multiple templates are provided (Fig. 19.8). Each has a tube (or key) with a slightly larger diameter than the osteotomy drills. These templates can be secured to the existing teeth or

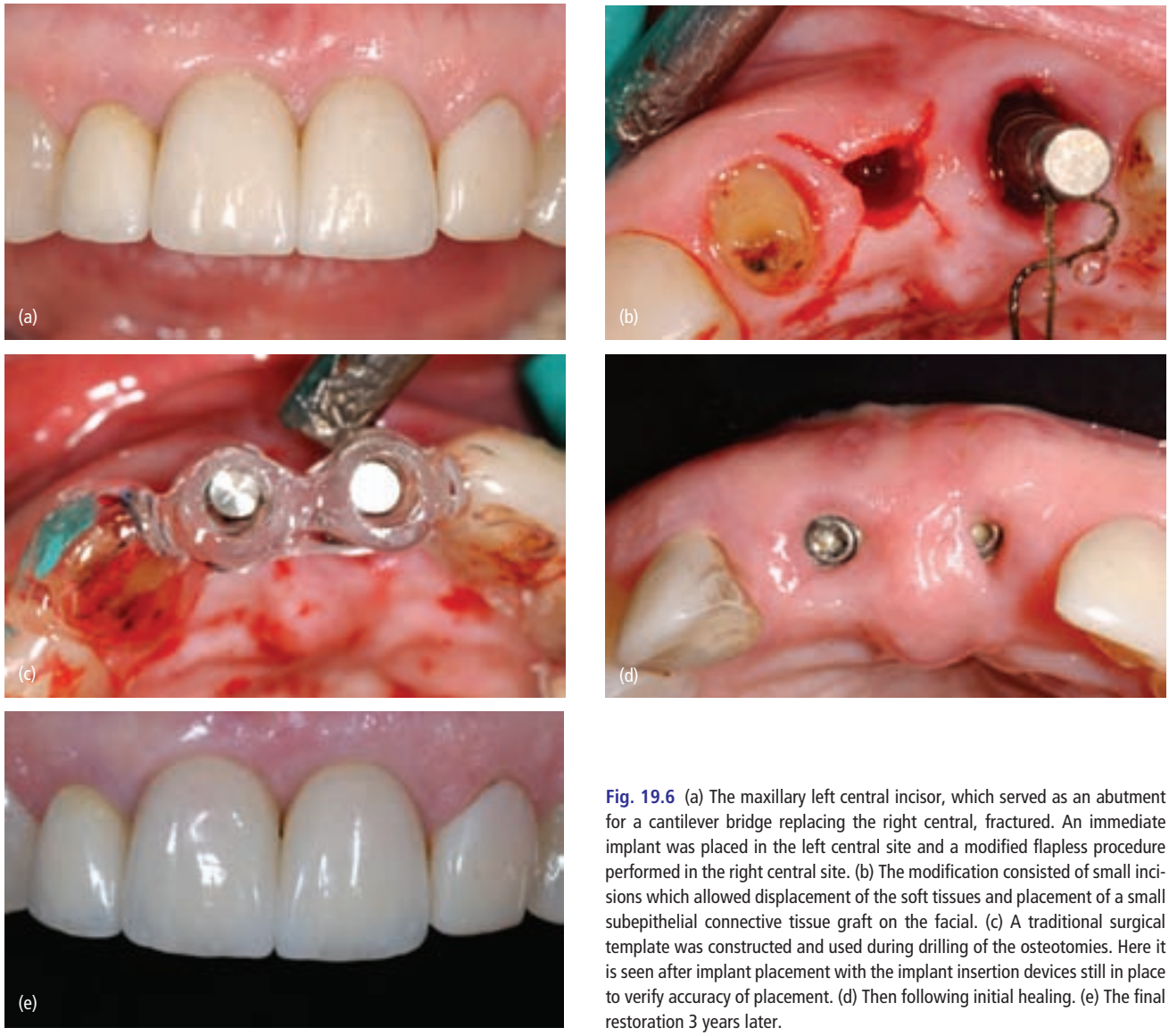


Fig. 19.6 (a) The maxillary left central incisor, which served as an abutment for a cantilever bridge replacing the right central, fractured. An immediate implant was placed in the left central site and a modified flapless procedure performed in the right central site. (b) The modification consisted of small incisions which allowed displacement of the soft tissues and placement of a small subepithelial connective tissue graft on the facial. (c) A traditional surgical template was constructed and used during drilling of the osteotomies. Here it is seen after implant placement with the implant insertion devices still in place to verify accuracy of placement. (d) Then following initial healing. (e) The final restoration 3 years later.

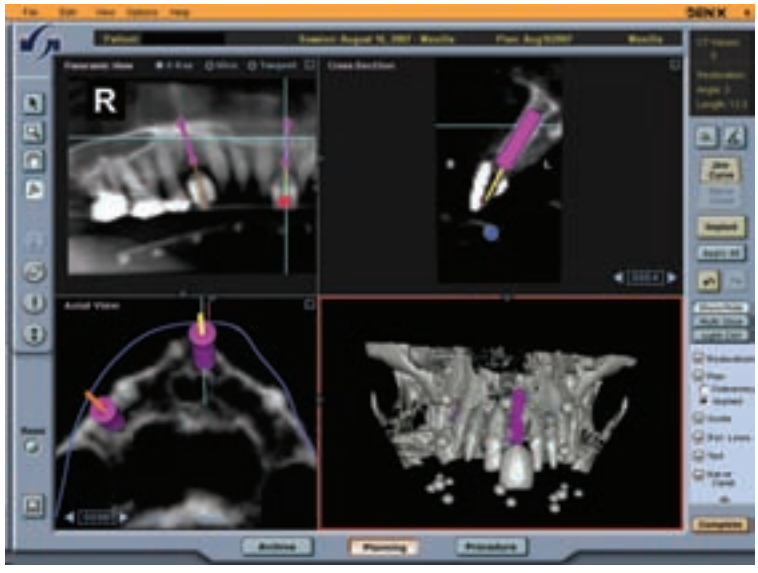


Fig. 19.7 Planning using a computerized implant planning program. The barium-impregnated mock-up of the final proposed restoration described in Fig. 19.1 aids digital implant placement.

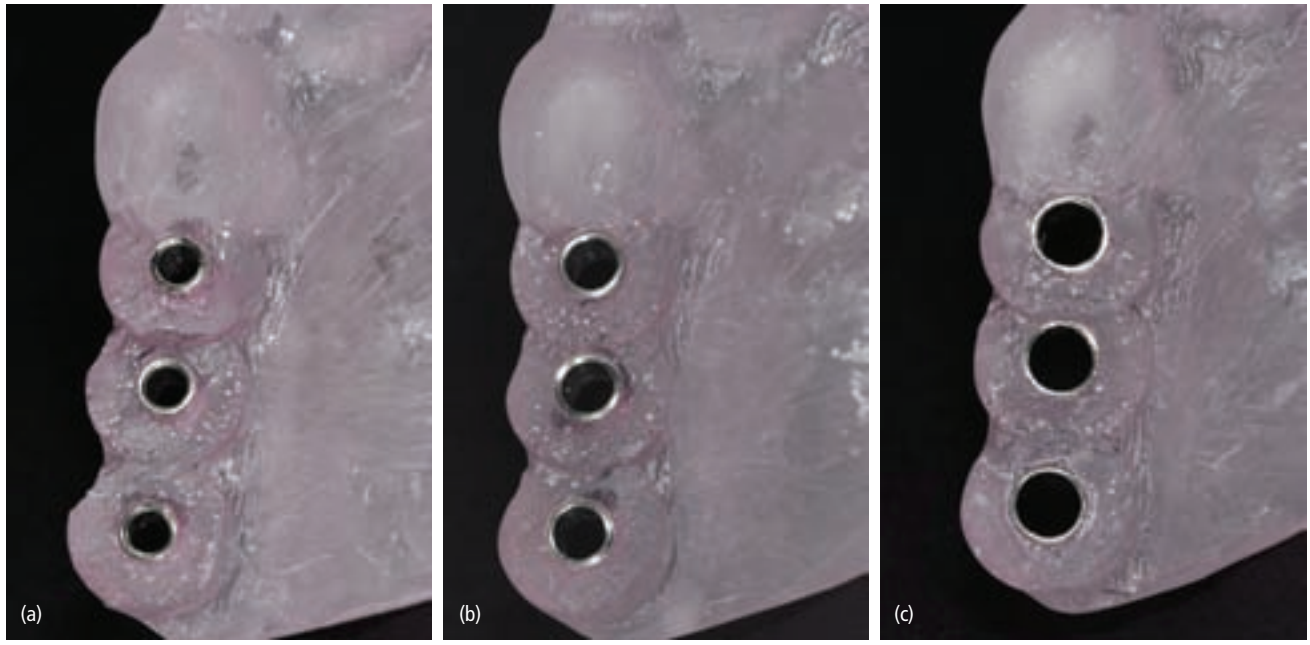


Fig. 19.8 A digital plan containing implant avatars placed in desired positions was sent for fabrication of guidance templates. The keys that direct the drills come in successively larger diameters.

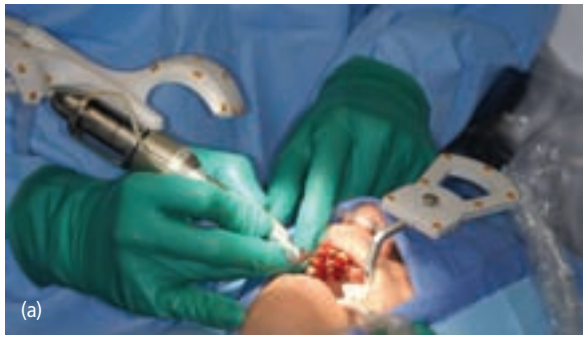
bone or can be supported by the mucosa, depending on the clinical situation and the number of natural teeth remaining.

In compromised flapless sites, guidance can be an important aid compared to surgery performed without a template or using templates fabricated by the traditional method. The relationship of the implant to the alveolar bone and the proposed final restoration and contiguous structures can be more precisely defined when using guidance than with traditional templates. The accuracy of these devices depends on many factors. Accuracy is compromised when there is any distortion in the CT scans fed into the program. Ideal implant placement is also dependent on the thoroughness of treatment planning, the accuracy of construction of the template, and the appropriate use of the template by the surgeon (14).

Traditional CT scans can manifest significant distortions which can negatively affect the clinical outcome of implant placement unless the tomograms are corrected for distortion (15). At present, guidance programs do not allow distortional corrections. CBCTs are more accurate but still contain some distortions, which may negatively affect clinical outcomes. Additional potential problems include inaccuracy in the study cast sent for fabrication of the surgical templates and inaccuracies in the template created during fabrication. These concerns are especially critical in flapless implant placement because the operator, when drilling, is totally dependent on the accuracy of the template. The surgeon cannot see the drill or its relation to the digital plan or to the surgical site. Examination of numerous templates made by various companies reveals that the discrepancy between the size of the implant drill and that of the tube (or key) in the template can allow for significant variations in positioning of the osteotomy. In many instances, especially when flapless surgery is used, this discrepancy can result in significant deviation from the proposed osteotomy site and a malpositioned implant.

Navigation

The use of surgical navigation (also called robotic surgery) allows the implant surgeon to monitor directly the osteotomy drill superimposed on the previously constructed digital plan, as well as the relationship of the osteotomy drill to cross-sections of the tomogram containing the digital implant avatar. In one system this is made possible by a series of light-emitting diodes (LEDs), one set of which is attached to the patient and another to the implant handpiece (IGI Image Navigation) (Fig. 19.9). The information from the LEDs is picked up by an infrared camera and transmitted to the central processing unit (CPU) of the computer attached to the camera. The patient's position in space along with the drill's position in space is superimposed on the digital implant plan and displayed on a monitor. Based on the monitor images, the operator can then make appropriate facial and lingual modifications in the drill path in real time during the surgical procedure. Further accuracy is provided by coordinate graphs, which indicate the relationship of the drill mesially, distally, facially, and lingually, and in terms of angulation and depth related to the digital plan



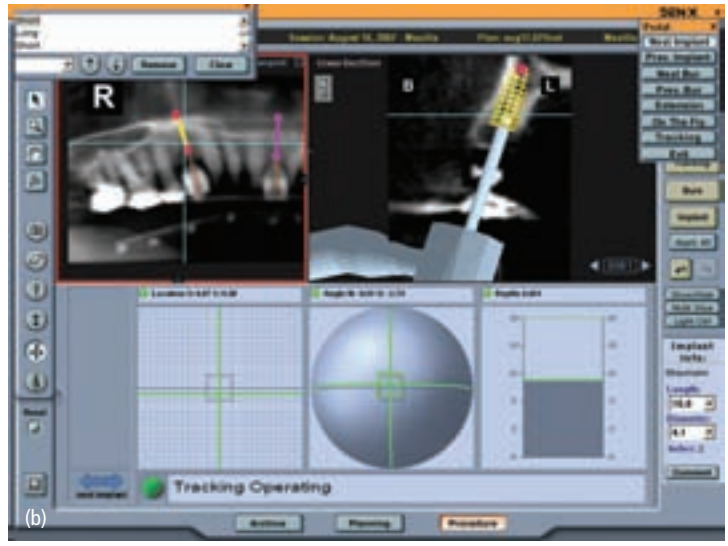


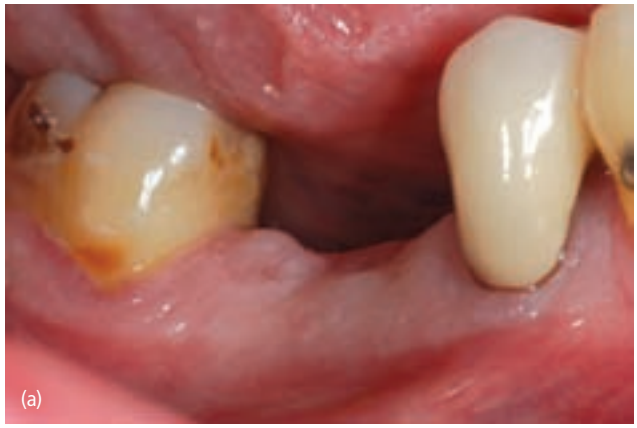
Fig. 19.9 Navigation features light-emitting diode (LED) arrays attached to the implant handpiece (left) and patient. Signals from these LEDs are picked up by an infrared camera then superimposed on the digital plan previously fed into the computer. The operator watches a monitor which contains guides that allow the operator to follow the planned drilling location accurately.

previously placed into the computer. This approach has been shown to be accurate to within fractions of a millimeter and allows the operator more control when compromised anatomy is found at the implant site (15) (Figs 19.10, 19.11). The present iteration of this navigation device is very accurate but has a steeper learning curve than guidance.

Regardless of the approach used, perfect placement does not always occur. Therefore, in areas that are compromised, an initial osteotomy of 6 mm (where appropriate) using the smallest twist drill is made. A radiopaque marker (a modified depth indicator) is placed in the osteotomy site and a radiograph is exposed (Fig. 19.10). This will locate the mesiodistal position of the osteotomy. When using flapless procedures, placing a finger against the buccal or lingual plate at the osteotomy site during drilling can often indicate whether the drill is close to penetrating the bony plate. If this occurs the operator can redirect the osteotomy drill.

Treatment of complications

The incidence of inappropriate placement using flapless procedures is high. If the osteotomy does not result in complete bony coverage of the implant (i.e. produces a bone fenestration or dehiscence), full-thickness mucoperiosteal flaps should be raised followed by guided bone regeneration to cover the exposed implant surface (Fig. 19.12). If correction during surgery is possible this approach is preferable. If the problem is discovered after the implant is osseointegrated several approaches are possible. If a small portion of the implant is exposed through the facial or lingual plate of bone but this produces no clinical signs or symptoms, these implants may be left undisturbed. However, if they are of concern to the patient or therapist, then appropriate treatment often includes reducing the exposed portion of the implant to the level of the bone (Fig. 19.13). Small portions of the implant still exposed but within the bony housing can also be treated with guided bone regeneration. In some



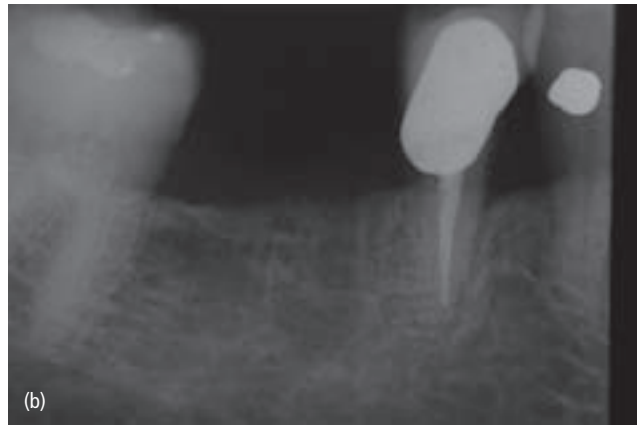
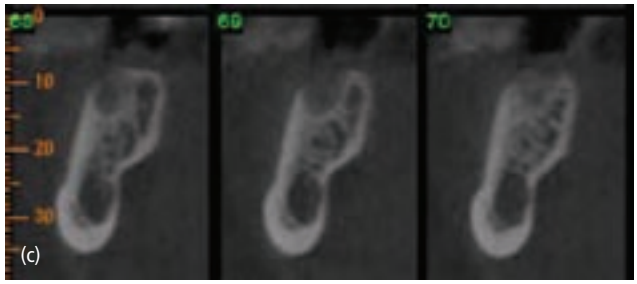
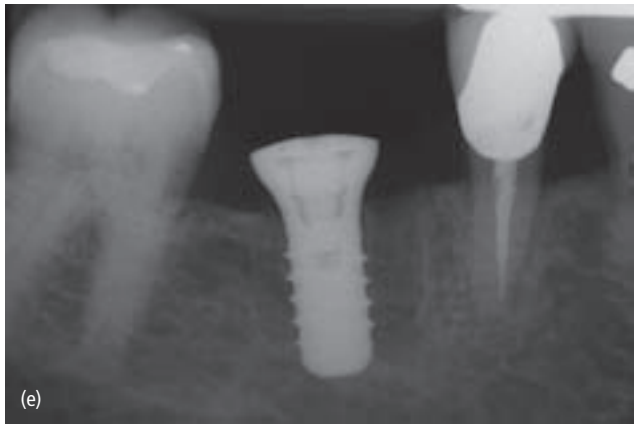
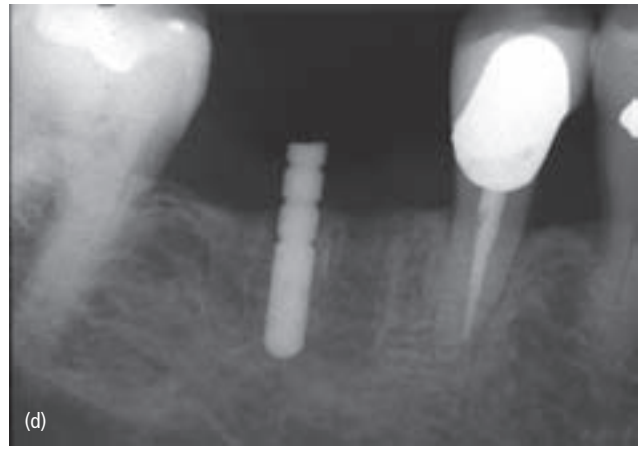


Fig. 19.10 (a, b) The mandibular first molar had been lost several months before the patient's initial visit.







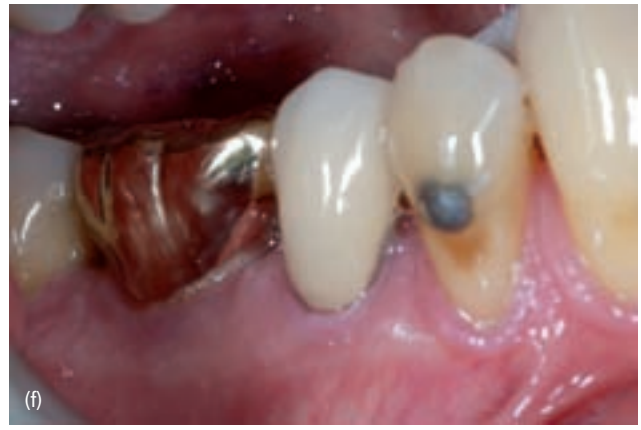


Fig. 19.10 ***(cont'd)*** (c) A CT image was taken and placed into a computer-aided navigation device. Following planning this device was used during implant placement. (d) Intraoperative radiographs were used to verify the position. (e) The implant was placed without raising a flap and (f) later restored.

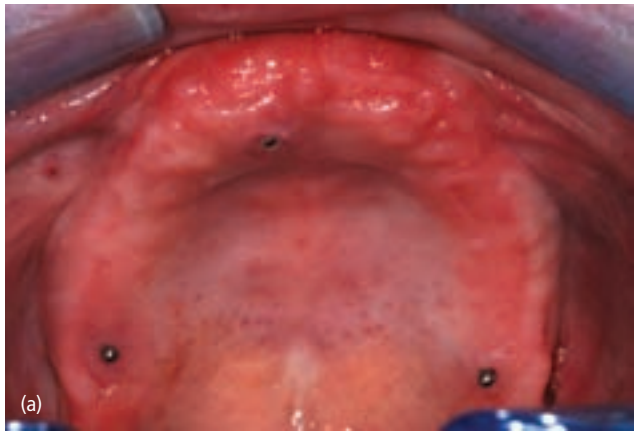


Fig. 19.11 (a) Occlusal view of a totally edentulous maxilla after bilateral maxillary sinus elevations. Three reduced-diameter implants have been placed which will serve as retention devices for a barium-impregnated wax-up of the final proposed restoration. (b) The barium-impregnated wax-up has been attached to a stent which will then be attached to the three reduced-diameter implants previously placed. These will help in placement of the guide during a cone-beam computed tomogram (CBCT).

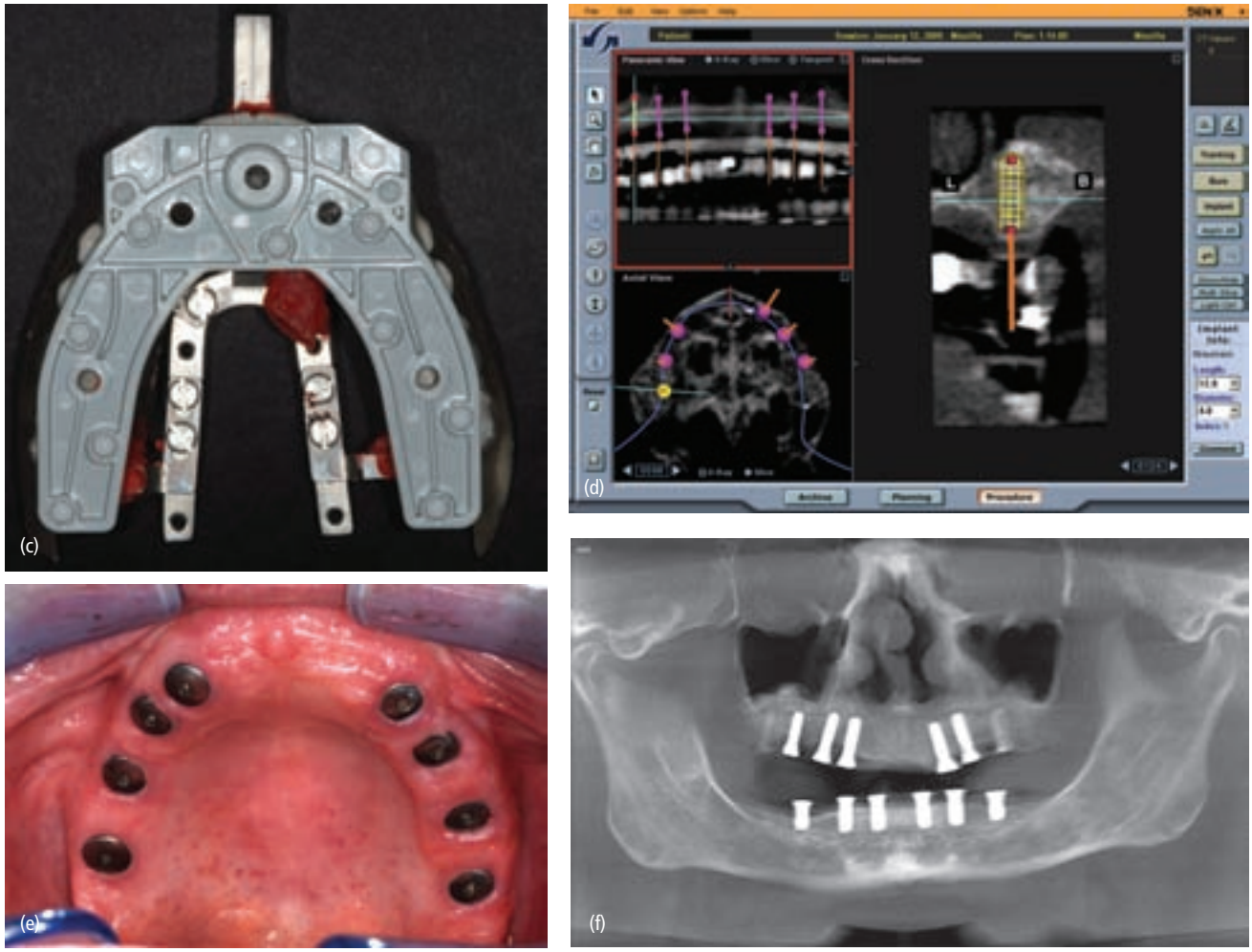


Fig. 19.11 ***(cont'd)*** (c) Before the CBCT is exposed, a horseshoe containing nine ceramic fiducials is luted to the wax-up shown in (b). These elements are placed on the reduced-diameter implants before the CBCT is exposed. (d) The CBCT has been fed into the CPU of the navigational device. Marking the fiducials in the planning program eliminates any distortion. Digital avatars are then placed into the planning program and appropriately related to the available bone and the proposed final restorations modeled here by the barium-impregnated representations of the teeth. (e) Navigation is then used for implant placement (described in detail in other areas of this chapter). Seen here is the final implant placement in the maxilla. (f) A panoramic film of the implant placement approximately 30 days after surgery. Successful implant orientation was possible in this case because of an abundant amount of keratinized tissue in the implant sites and the accuracy with which the implants are placed using navigation techniques.

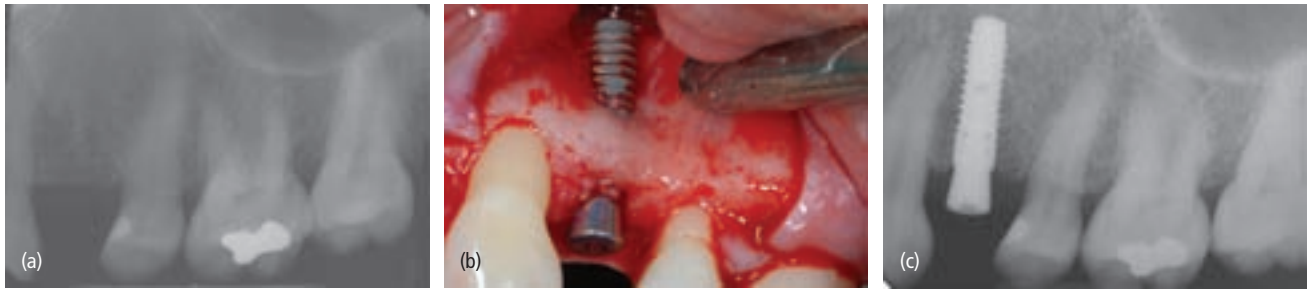


Fig. 19.12 This implant was placed with a flapless protocol using a set of guidance templates. The play in the guide tubes allowed deviation from the planned osteotomy course, resulting in perforation of the facial plate of bone. This was detected clinically. A full-thickness mucoperiosteal flap was then raised and guided bone regeneration performed. The implant was successfully restored.

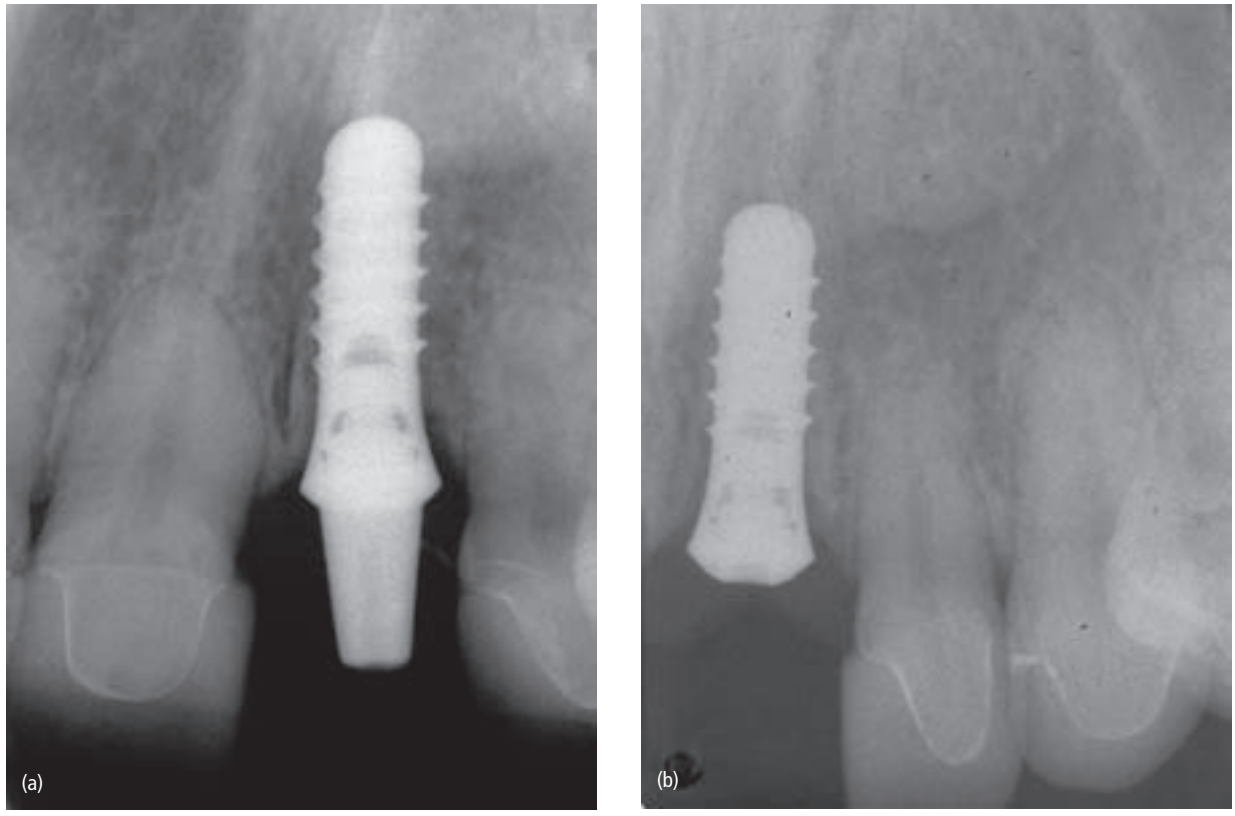


Fig. 19.13 This implant was placed in close proximity to the incisive canal. Nerve-like pain was felt when the implant was loaded. (a) The implant shoulder was cut back level with the bone and soft tissue was allowed to cover it. (b) A fixed partial denture was placed.

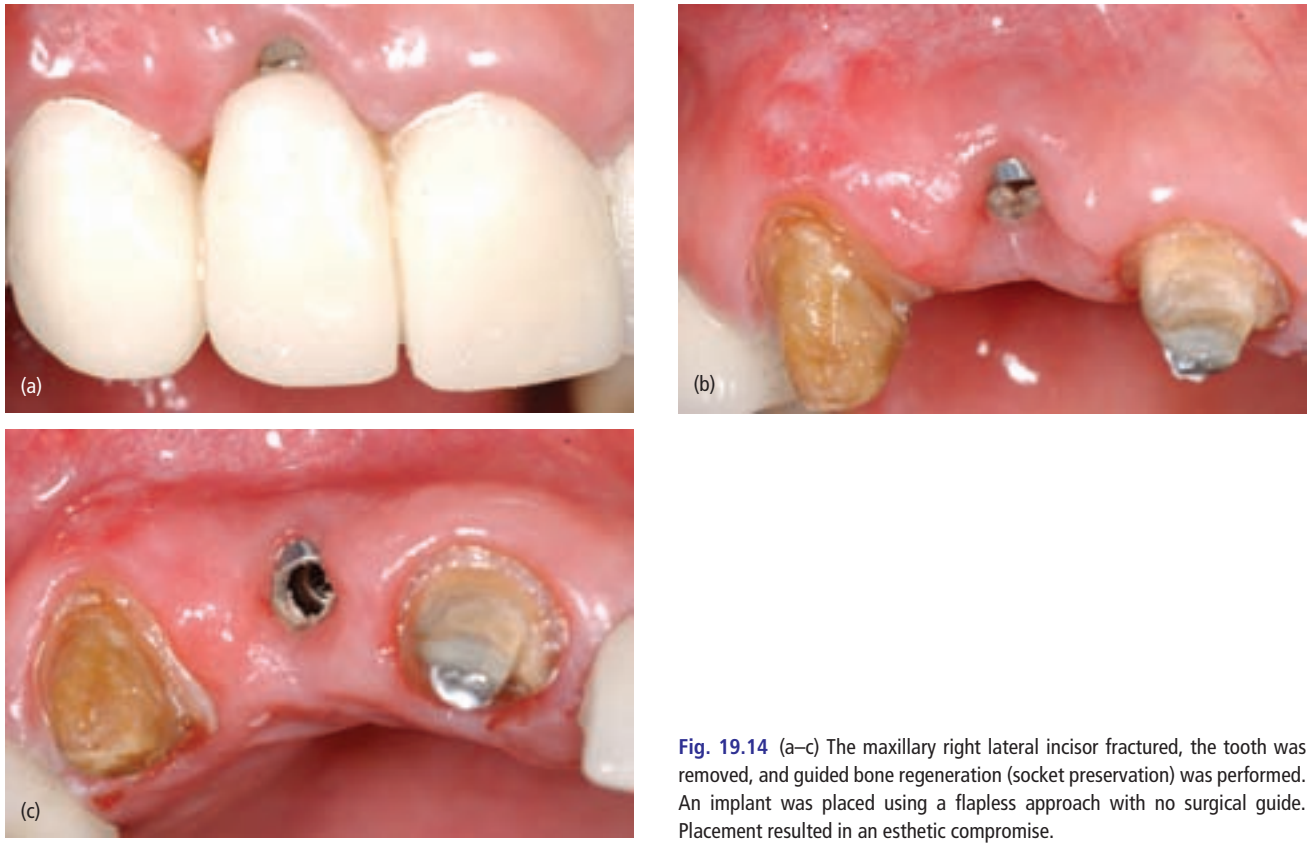


Fig. 19.14 (a–c) The maxillary right lateral incisor fractured, the tooth was removed, and guided bone regeneration (socket preservation) was performed. An implant was placed using a flapless approach with no surgical guide. Placement resulted in an esthetic compromise.

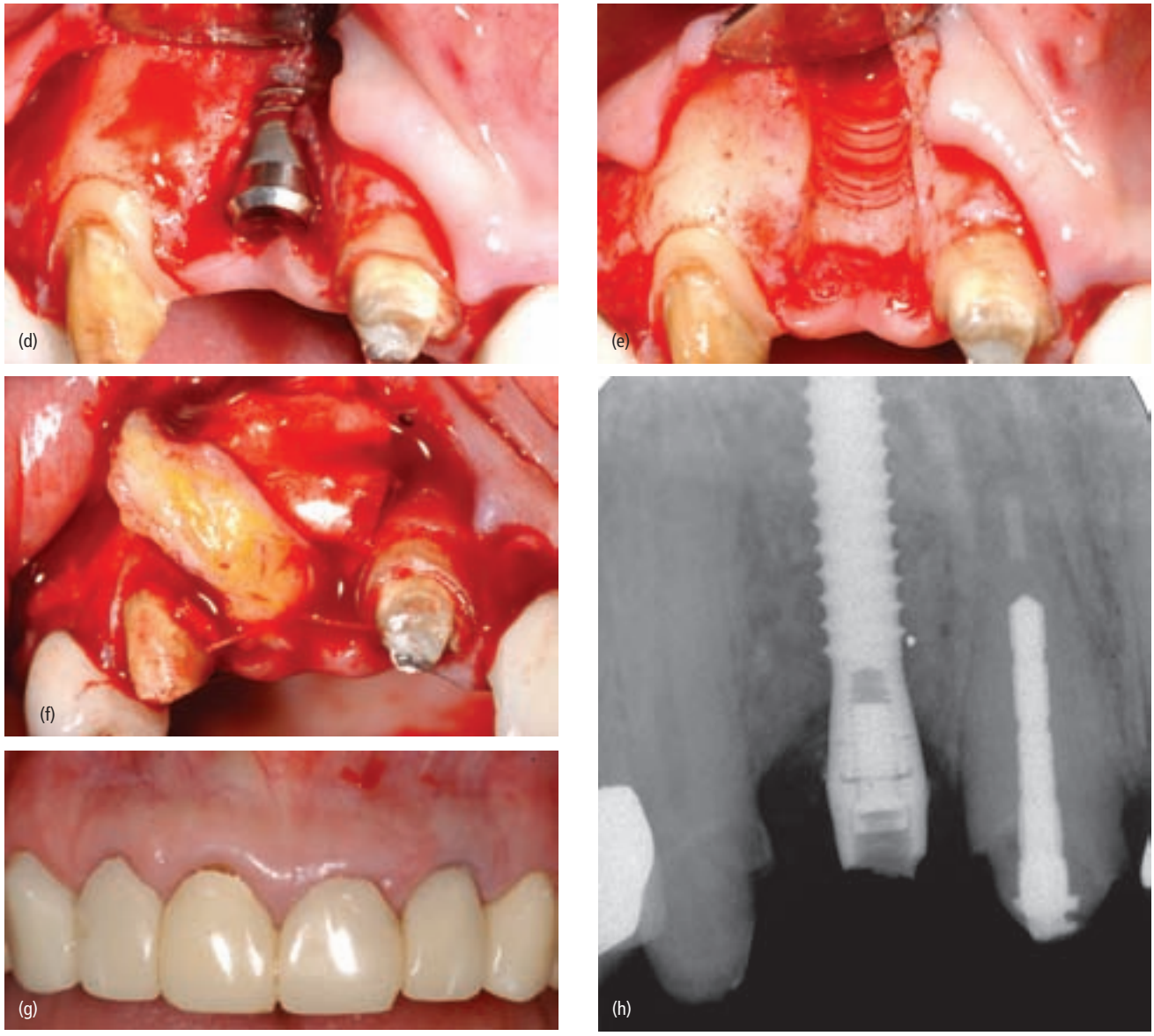


Fig. 19.14 ***(cont'd)*** (d, e) Following receiving informed consent from the patient, the implant was removed and guided bone regeneration and a soft-tissue graft were used to regenerate lost tissue. (g, h) Subsequently, another implant was placed and restored.

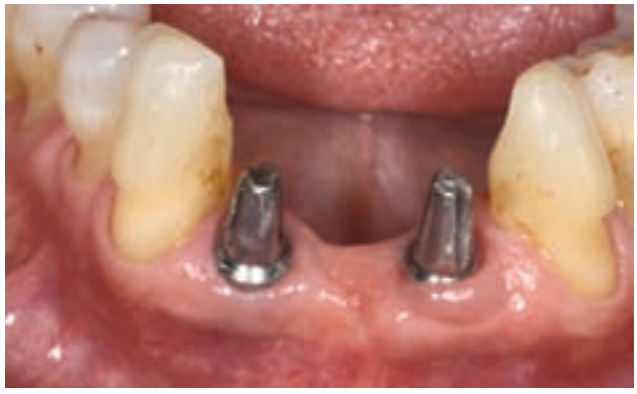


Fig. 19.15 This patient received immediate implants following extraction of several mandibular anterior teeth. Preoperatively it was noted that there was no keratinized gingiva on the facial of the teeth to be removed. Consequently, to reduce tissue mobility and subsequent discomfort, a subepithelial tissue graft was placed on the facial of the implant sites immediately after fixture installation.

cases removal of the implant is indicated (Fig. 19.14). It is also possible to section all portions of the implant coronal to the alveolar housing and cover the implant with a soft-tissue graft. This procedure has been termed "putting the implant to sleep" by some individuals. In these cases, if the implant irritates the soft tissue it may need to be removed.

In those instances where the band of keratinized tissue is inadequate following healing of the implant, free gingival grafts or subepithelial connective tissue grafts can be placed (15–24) (Fig. 19.15).

Summary

Flapless surgical placement of dental implants has many desirable features, including reduced surgical time, bleeding, swelling, and morbidity. However, in a significant number of cases treated in this manner the implant is placed in a less than optimal position. If this approach is to be used, the surgeon should thoroughly understand the anatomy of the implant site and the implant be placed in as ideal a position as possible. The clinician should be familiar with adjunctive surgical procedures such as guided bone regeneration which may be necessary to treat any exposure of the implant. Accuracy can be increased by the use of digital planning placement programs and surgical guides.

Take-home hints

- Flapless surgery reduces patient morbidity and operating time.
- Without proper planning and placement, flapless surgery frequently results in compromised results because of incorrect implant positioning.
- To reduce problems these procedures should be performed in conjunction with CT or CBCT scans. Placement monitors (X-rays with direction indicators) can improve the accuracy of placement.
- Guidance and navigation can improve placement accuracy, but these methods are expensive and have a steep learning curve.
- Implants fare better when surrounded by keratinized gingiva.
- Where minimum gingiva is found, flaps designed to reposition soft tissues or presurgical or postsurgical soft-tissue grafts to enhance keratinized tissue are recommended.
- The clinician should be familiar with various hard- and soft-tissue augmentation techniques to treat complications as they occur.

Potential conflicts of interest

The author of this chapter has received lecture fees and research support from Straumann and is an uncompensated consultant to Image Navigation.

References

1. Campelo LD, Camara JR. Flapless implant surgery: a 10-year clinical retrospective analysis. *Int J Oral Maxillofac Implants* 2002; **17**: 271–6.
2. Al-Ansari BH, Morris RR. Placement of dental implants without flap surgery: a clinical report. *Int J Oral Maxillofac Implants* 1998; **13**: 861–5.
3. Cannizzaro G, Leone M, Consolo U, Ferri V, Esposito M. Immediate functional loading of implants placed with flapless surgery versus conventional implants in partially edentulous patients: a 3-year randomized controlled clinical trial. *Int J Oral Maxillofac Implants* 2008; **23**: 867–75.
4. Laney WR, ed. *Glossary of oral and maxillofacial implants.* Berlin: Quintessence, 2007.
5. Zigdon H, Machtei EE. The dimensions of keratinized mucosa around implants affect clinical and immunological parameters. *Clin Oral Implants Res* 2008; **19**: 387–92.
6. Block MS, Kent JN. Factors associated with soft- and hard-tissue compromise of endosseous implants. *J Oral Maxillofac Surg* 1990; **48**: 1153–60.
7. Warrer K, Buser D, Lang NP, Karring T. Plaque-induced peri-implantitis in the presence or absence of keratinized mucosa. An experimental study in monkeys. *Clin Oral Implants Res* 1995; **6**: 131–8.
8. Bouri A, Bissada N, Al-Zahrani MS, Faddoul F, Nouneh I. Width of keratinized gingiva and the health status of the supporting tissues around dental implants. *Int J Oral Maxillofac Implants* 2008; **23**: 232–6.
9. Higginbottom FL, Wilson TG. Three-dimensional templates for placement of root-form dental implants: a technical note. *Int J Oral Maxillofac Implants* 1996; **11**: 787–93.
10. Kopp KC, Koslow AH, Abdo OS. Predictable implant placement with a diagnostic/surgical template and advanced radiographic imaging. *J Prosthet Dent* 2003; **89**: 611–15.
11. Van de Velde T, Glor F, Debruyn H. A model study on flapless implant placement by clinicians with a different experience level in implant surgery. *Clin Oral Implants Res* 2007; **19**: 66–72.
12. Sennerby L, Rocci A, Becker W, Jonsson L, Johansson L, Albrektsson T. Short-term clinical results of Nobel direct implants: a retrospective multicentre analysis. *Clin Oral Implants Res* 2008; **19**: 219–26.
13. Komiyama A, Klinge B, Hultin M. Treatment outcome of immediately loaded implants installed in edentulous jaws following computer-assisted virtual treatment planning and flapless surgery. *Clin Oral Implants Res* 2008; **19**: 677–85.
14. Elian N, Jalbout ZN, Classi AJ, Wexler A, Sarment D, Tarnow D. Precision of flapless implant placement using real-time surgical navigation: a case series. *Int J Oral Maxillofac Implants* 2008; **23**: 1123–7.

15. Meyer U, Wiesmann HP, Runte C, Fillies T, Meier N, Lueth T, Joos U. Evaluation of accuracy of insertion of dental implants and prosthetic treatment by computer-aided navigation in minipigs. *Br J Oral Maxillofac Surg* 2003; **41**: 102–8.
16. Silverstein LH, Lefkove MD. The use of the subepithelial connective tissue graft to enhance both the aesthetics and periodontal contours surrounding dental implants. *J Oral Implantol* 1994; **20**: 135–8.
17. ten Bruggenkate CT, Krekeler G, Kwast WVD, Oosterbeek H. Palatal mucosa grafts for oral implant devices. *Oral Surg Oral Med Oral Pathol Oral Radiol Endodont* 1991; **72**: 154–8.
18. Simons A, Darany D, Giordano J. The use of free gingival grafts in the treatment of peri-implant soft tissue complications: clinical report. *Implant Dent* 1993; **2**: 27–30.
19. Simons AM, Baima RF. Free gingival grafting and vestibuloplasty with endosseous implant placement: clinical report. *Implant Dent* 1994; **3**: 235–8.
20. Han TJ, Klokkevold PR, Takei HH. Strip gingival autograft used to correct mucogingival problems around implants. *Int J Periodontics Restorative Dent* 1995; **15**: 404–11.
21. Hoelscher DC, Simons AM. The rationale for soft-tissue grafting and vestibuloplasty in association with endosseous implants: a literature review. *J Oral Implantol* 1994; **20**: 282–91.
22. Nemcovsky C, Artzi Z. Split palatal flap. II. A surgical approach for maxillary implant uncovering in cases with reduced keratinized tissue: technique and clinical results. *Int J Periodontics Restorative Dent* 1999; **19**: 385–93.
23. Azzi R, Etienne D, Takei H, Fenech P. Surgical thickening of the existing gingiva and reconstruction of interdental papillae around implant-supported restorations. *Int J Periodontics Restorative Dent* 2002; **22**: 71–7.
24. Nemcovsky C, Moses O. Rotated palatal flap. A surgical approach to increase keratinized tissue width in maxillary implant uncovering: technique and clinical evaluation. *Int J Periodontics Restorative Dent* 2002; **22**: 607–12.

Chapter 20

Complications related to immediately loaded dental implants

Jeffrey Ganeles DMD, FACD *and David Grossberg* BDS, FICD

Introduction

Immediately loading dental implants at the time of surgical placement is a treatment option that offers many potential advantages in patient care. Whether accomplished for a single tooth or a complete dentition, allowing patients to combine surgical and fixed restorative implant procedures into a single treatment visit is almost always more appealing than conventional alternatives which require multiple surgical and restorative visits. Of course, in choosing this option, the clinician should be assured a similar result in terms of success rate, esthetics, and complication rate to conclude that immediate implant loading is at least equal to other treatment protocols. The purpose of this chapter is to highlight some of the risks and complications associated with the use of this protocol and then explore principles and techniques recommended to avoid these problems. In addition, the treatment of implant complications with this protocol, if and when they occur, will be discussed.

Several definitions for variations on immediate loading are referred to in the Glossary of Oral and Maxillofacial Implants (GOMI) 2007 (1). Terms used to describe types of immediate loading include immediate functional loading, immediate non-functional loading, immediate provisionalization and immediate restoration. The basic differences between the terms relate to whether the implant-supported restorations are placed in full occlusal contact with the opposing dentition or are left short of contact on the day of implant placement. Even if the teeth are not in direct contact, it is understood that forces may still be applied to the restorations or implants supporting them through lip or tongue musculature, parafunction, habits with or without foreign objects, or chewing a food bolus.

According to the GOMI, complications are unexpected deviations from the normal treatment outcome, which may include patient injury, surgical mishap, implant failure, or esthetic problems. Esthetic complications are further described as related to implant malposition, regardless of the implant loading time used. Of particular interest when discussing complications with immediate loading are the potential for increased rates of implant failures and esthetic problems that may be associated with accelerated loading protocols.

Complications addressed in this chapter that are associated with the immediate implant loading protocol include:

- failure of the implant to osseointegrate
- surgical complications
- esthetic complications
- implant malposition
- restorative complications
- complications with guided surgery and prefabricated restorations.

Failure to achieve osseointegration: etiology

Understanding osseointegration complications associated with immediate implant loading requires an understanding of the early wound healing of bone associated with implant placement. Raghavendra *et al.* (2) proposed a graphical curve to illustrate implant stability as a function of time immediately after placement (Fig. 20.1). They

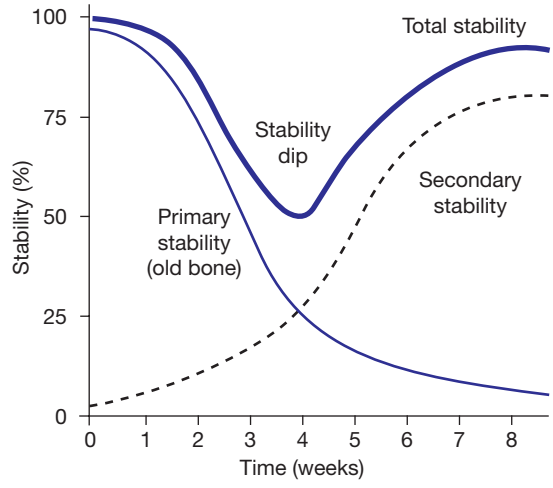


Fig. 20.1 Graph representing changes in implant primary and secondary stability over time.

suggested that implant stability is maximized at initial placement owing to the macroretentive features such as threads, surface area, and surface texture combined with the wedging effect from the undersized osteotomy. Early healing begins with osteoclastic activity causing a reduction in implant stability. This gradual loosening of the implant continues for several weeks until osteoblastic activity deposits new bone onto the implant surface, leading to osseointegration. The length of these periods varies with many factors including implant size, shape and surface morphology, bone density, patient health, osteotomy technique, and bone physiology. These dynamic alterations in implant stability have been confirmed by resonance frequency analysis studies (3)

Implant stability has been recognized, in the dental literature, as a prerequisite for successful osseointegration (4–9). The conclusions of these studies indicate that biocompatible materials such as titanium dental implants will osseointegrate provided that osteotomies have been prepared with adequate attention to good sterility and minimal heat generation if the implants remain stable during healing with the bony interface. However, it has been shown that absolute rigidity of the implant may not be required for osseointegration to occur. Instead, a "threshold of micromotion" may be tolerated, still permitting osseointegration. While this value has not been determined, there is speculation that the tolerated movement may be in the range of 50–100 μm, which is similar to the mobility expected from a stable posterior tooth in normal function (10).

Combining the high implant success rates shown with conventional loading (11, 12) with the evidence outlined above, it can be concluded that despite the reduction in stability that occurs during normal healing, mobility does not usually increase to a point that would cause implant failure. Similarly, there is abundant clinical (13–24) and some scientific (25–27) evidence suggesting that with few exceptions (28, 29) successful osseointegration can be achieved with an immediate implant loading protocol. This suggests that under conditions described in the clinical reports, loss of stability and mobility were not significant enough to cause implant failure. The reported success with immediately loaded implants appears to occur whether implants are placed in healed ridges or in extraction sockets (30, 31). In addition, there is growing evidence (27) that carefully applied forces may in some cases accelerate osseointegration and increase bone-to-implant contact.

Immediate loaded-Implant failure

Short implants

Etiology

The fact that the scientific literature reports that virtually all immediately loaded or restored implants heal successfully without complications conflicts with traditional teaching and the clinical experience of many clinicians. Careful evaluation of some of the few reported failures of some authors may offer greater insight into factors that contribute to success or failure. Highlighting several articles and examining the etiology of failed implants may be instructive. Schnitman *et al.* (32, 33), often credited with initiating the study of immediate loading with osseointegrated implants, reported on early results in ten consecutively treated patients. Patients had rigid, screw-retained, full mandibular fixed prostheses attached to two to four immediately loaded implants. Adjacent unloaded implants were allowed to heal conventionally. Four of 28 (14.3%) immediately loaded implants failed while 100% of the conventionally loaded implants osseointegrated. In discussion of the failed implants, the authors noted that most of the failed implants were placed posterior to the mental foramen and were 10 mm or less in length. Immediately loaded implants that were longer (>10 mm) and were placed anterior to the mental foramen tended to integrate and remain stable for up to a 10-year evaluation period.

Prevention

The authors speculated that the implant failures may have been related to the use of short implants in the posterior mandible where there is often limited quantity and poor-quality bone and the where the highest occlusal forces are concentrated. Longer implants in the anterior mandible showed virtually 100% integration rates.

Implant macromotion from repeated removal of the provisional restoration

Etiology

In another early study, which included multiple implant systems for full-arch immediate loading, Tarnow *et al.* (34) compared success of immediately loaded implants to those placed with a conventional delayed loading protocol in the same patients. While results for the two groups were similar, 97% (67/69) immediately loaded versus 97% (37/38) conventionally loaded, the authors noted that the immediately loaded failures were concentrated in the first few patients in whom the provisional restorations were frequently removed in order to test implant stability using a Periotest (Siemens AG, Bensheim, Germany) device.

Prevention

This study suggested that the implant failures were related to the repeated removal of the provisional restoration producing macromotion. When the authors

subsequently discontinued this part of the protocol, the later patients had no failures.

Use of machined implant surfaces

Etiology

Lower success rates have been reported with single-tooth, immediate-implant restorations. These studies include Ericsson *et al.* (35), Rocci *et al.* (36), and Malo *et al.* (37), who reported 85.7%, 81.5%, and 85.2% success rates in their respective studies. One of the common elements in their studies was the use of machined surface implants for all of the patients included in these reports.

Prevention

In a follow-up study, Rocci *et al.* (38) treated patients with the same surgical and restorative protocols but randomized the implant surfaces used between machined titanium and TiUnite®, noting a significant improvement in success rate with the roughened surface. The difference in success rates was even more pronounced when evaluating implants placed in type IV bone, where five out of 11 machined surface implants compared to one out of 12 rough surfaced implants failed to integrate. Schincaglia *et al.* (39) found similar results comparing machined and roughened surface implants in partially edentulous patients. They reported no failures with rough surface implants and lost two out of 22 machined surface implants. In addition, they noticed that after 1 year, radiographic bone levels on the rough surface implants appeared to be more stable than those surrounding machined surface implants.

Press-fit implant design

Etiology

Chaushu *et al.* (40) noted an 82.4% success rate in immediately loaded hydroxyapatite-coated cylindrical implants placed into extraction sockets, compared to 100% success when placed in healed ridges. This relatively low success rate led the authors to recommend against immediately loading press-fit implants placed into immediate extraction sockets. The fact that the implants did not have macroretentive features such as screw threads may have also played a significant role in their relatively poor integration rate

Prevention

In comparison to other authors such as Kan *et al.* (41) who reported 100% success in extraction sockets with threaded implants, it is tempting to conclude that one key difference between their results may be the shape of the implants, despite both studies using roughened surfaces. Since almost all modern implants have some enhanced macroretentive features such as screw threads, press-fit design is not a major concern today.

Traumatic site preparation

Etiology

Site preparation techniques may have an effect on implant success. Many authors suggest underdrilling the apical width of osteotomies to improve apical bone compaction and initial stability in poor-quality bone (42–44). However, Degidi and Piattelli (45) reported on a subgroup of single-tooth immediately loaded Frialit2 implants and identified a cluster of failures in sites where site preparation was accomplished with bone condensation alone. They suggested that this method of osteotomy preparation might have contributed to implant failure. Confirming similar findings in a dog study, Stavropoulos *et al.* (46) reported 100% failure of implants in sites prepared exclusively with osteotomes. This further supports the observation that bone compaction alone may be detrimental to normal wound healing leading to osseointegration.

There is some histologic and clinical evidence indicating that bone condensation may delay bone wound healing and reduce implant stability, which can be detrimental to success with immediate loading. Nkenke *et al.* (47) and Büchter *et al.* (48) noted a lower bone-to-implant contact ratio compared with drilled osteotomies, even after 28 days of healing, delaying the secondary stability required to accomplish long-term osseointegration. In their studies, implant stability was reduced after several weeks of healing, leading them to recommend against condensation for site preparation for early loading protocols.

Overcompression of bone has been linked to implant failure, particularly in dense bone (49). The limited data suggest that there may be an optimal degree of tightness between the osteotomy and implant to promote normal healing, regardless of the loading protocol. Traumatic preparation causing bone fracture and excessive compression appear to delay healing, which could be detrimental to results.

Prevention

There have been limited and conflicting reports about the effects of bone condensation on early healing. Given this controversy, it appears that the degree of acceptable bone compression has either not been described or may not be clinically measurable. As a result, it is recommended that bone condensation be limited to apical osteotomy preparations in loose trabecular bone, using

more precise, less traumatic drilling preparations for denser, more cortical sites.

Inadequate initial stability or inadequate implant support

Etiology

Horwitz *et al.* (29) reported a very low success rate of 52% for immediately loaded maxillary full-arch cases in patients who previously suffered from advanced periodontitis. By comparison, Jaffin *et al.* (19) reported a success rate of 93% in a larger, but seemingly similar population. Reviewing the details of their techniques, several subtle differences emerge. Horwitz *et al.* reported that only three or four strategically positioned implants were used to support the maxillary provisional restorations and that these implants were not necessarily selected for optimal initial stability as measured by the implant stability quotient (ISQ) (50) or torque resistance. Of the 12 implants that failed, eight had initial stability measurements that were below the authors' minimum ISQ threshold value of 60. They also noted that the abutments used for the provisional restorations were "gold-plastic" and may have had reduced rigidity, leading to implant micromotion. In comparison to Jaffin's techniques and others (51, 52) who reported high success rates, Horwitz's methods appear to have fewer implants with less initial stability and less emphasis on rigidity of the provisional restoration than those reporting higher success rates.

Prevention

Wound healing studies and clinical recommendations stress the need to maintain implant stability during healing. Paramount to this principle is the assumption that the implants begin the healing process with excellent stability. Therefore, if initial stability is not high, implants should not be restored with an immediately loaded protocol.

There are numerous methods to assess implant stability after placement, including insertion torque value, Periotest (53), and Osstell (Osstell AB, Göteborg, Sweden) (54). Insertion torque is estimated from the surgical drilling unit, which cannot be assumed to be precise or accurate. Typically, the values read from a drilling unit are the maximum torque that will be delivered during implant insertion. As a result, there is no way to know how much torque was used to seat an implant unless the handpiece stops during insertion. Most surgeons feel that that they can judge implant stability by the feel of the implant as it is being threaded into the osteotomy, using feedback from the drilling device or the rachet of the hand insertion instruments. A recent publication by Degidi *et al.* (55) suggests that surgeon's perceptions are inaccurate when compared to objective tests. Of the available stability testing instruments, only the Osstell is currently commercially available. It also has the greatest amount of published information. However, it should be recognized that standards or threshold values for successful loading have not yet been verified, regardless of the anticipated loading protocol. A recent animal study has also questioned the accuracy of information gained from resonance frequency analysis (56), suggesting that other methods of stability measurement may be more accurate and appropriate.

Assessing sufficient implant support for a particular case is as much clinical judgment as an exact science. Factors that should be included in the decision process include the number of teeth to be replaced, bone quality and quantity in the anticipated implant sites, status of the opposing arch, parafunction, and anticipated restorative design. Implant size, shape, and surface also play a role in determining adequacy of support for a planned treatment. Degidi and Piattelli (45) recommended a mathematical formula of "prosthetic unit-to-implant ratio" of at least 1.4 in the maxilla and 1.5 in the mandible. Jaffin *et al.* (19) recommended selecting implant sites based on a minimum bone density value of 350 Hounsfield units. It should be recognized that these recommendations for the number of implants and bone density are not evidence-based statements, but empirical clinical impressions.

Recommendations

General recommendations to improve implant stability can be made based on accepted surgical and treatment planning principles. Selecting sites with good bone quality or engaging cortical bone without causing injury will increase initial stability.

Three-dimensional (3D) radiographic examination provides more comprehensive and accurate anatomic information than two-dimensional data. Recent evidence by Song *et al.* (57) suggests that there is a positive correlation between bone density as observed on a cone beam computed tomographic (CBCT) scan, bone quality, and initial implant stability as measured by Osstell ISQ. In addition, many computer-based imaging and planning software systems permit bone density analysis. Objective assessment of implant stability after placement should limit the possibility of loading implants with inadequate stability.

For fully edentulous cases, the use of at least four to six implants with adequate size and good stability and distribution around the arch is recommended for improved success. Mandibular cases may require fewer implants than maxillary cases owing to generally greater bone density and the better opportunity that exists to engage cortical bone anterior to the mental foramina. When

opposing arches are restored with removable prostheses, fewer implants have to be used to support an immediately loaded restoration.

Surgical complications related to immediate loading

Despite the conclusions from published literature that immediate loading is a predictable technique in implant dentistry, in many cases for almost all patients, numerous problems and potential complications must be considered.

Patient injury and material failure

Etiology

The major complications related to patient injury are not always directly related to immediate loading. Injury can result if a surgeon attempts to increase implant stability by placing longer or wider implants than would normally be warranted into the available bone, thus fracturing the alveolar ridge, perforating cortical plates of bone, or damaging vital structures.

Often in an attempt to increase initial stability, surgeons deliberately place implants into undersized osteotomies, resulting in alveolar fracture, mandibular fracture, or excessive bone compression which could lead to bone necrosis. Properly placed wide neck or tapered implants do not present an increased risk for crestal bone loss (58, 59). However, it should be recognized that there is a possibility of alveolar damage which may be magnified if tapered or wide platform implants are forced into dense bone without adequate osteotomy preparation. As reported by Bashutski (49), it is possible to overtorque implants so that the excessive pressure could lead to crestal bone necrosis and defect formation, inhibiting osseous replacement during the normal healing period.

Another problem with placing implants with excessive initial torque is that the implants themselves could fracture. Figure 20.2 is an example of a 5 mm diameter implant placed with extreme torque by an inexperienced surgeon attempting to increase implant stability, causing the implant to fracture vertically along the internal lobes during insertion.

Despite the belief that this implant would be stronger, it failed because of the surgeon's efforts to maximize initial stability for immediate loading. Moreover, trephine removal of the fractured implant resulted in significant loss of surrounding bone, compromising the site for future implant placement (Fig. 20.3).

Prevention

To prevent surgical injury to vital structures or trauma to surrounding structures during placement, surgeons must adhere to conventional practices and the manufacturer's guidelines for implant placement. Preoperative diagnosis and planning should create an awareness of anatomic limitations of a particular site, regardless of the loading protocol. Forcing implants into underprepared sites risks the biologic complications related to compromised healing or implant failure as well as material failure of the implant.

Excessive implant depth (deep placement)

Etiology

Since surgeons are aware that immediate loading depends on primary stability, there is often an effort to seat implants to the point where they have sufficient torque resistance. This often results in implants that are overtightened or threaded too deeply in an effort to

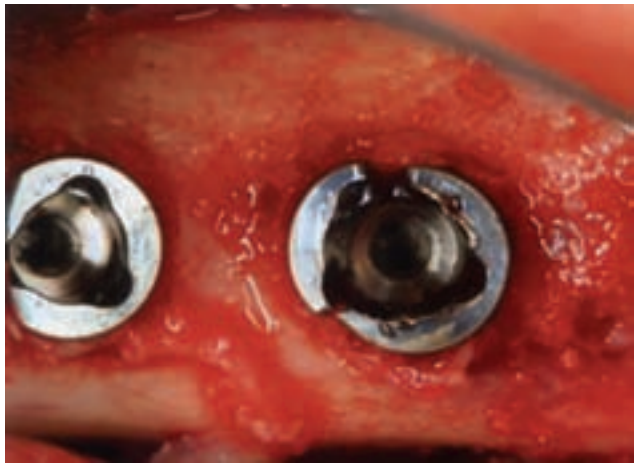


Fig. 20.2 A 5 mm wide implant vertically fractured from excessive insertion torque.

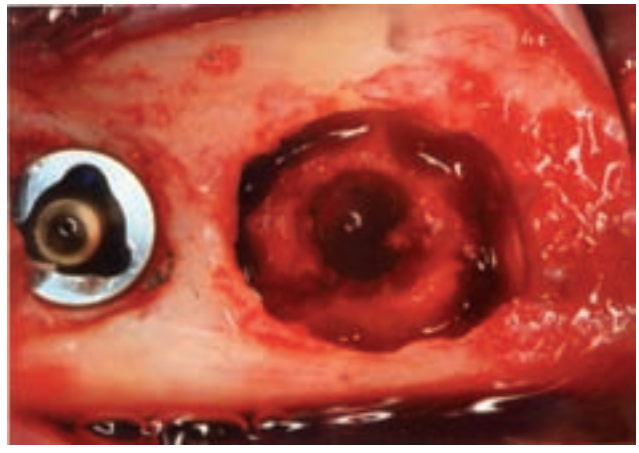
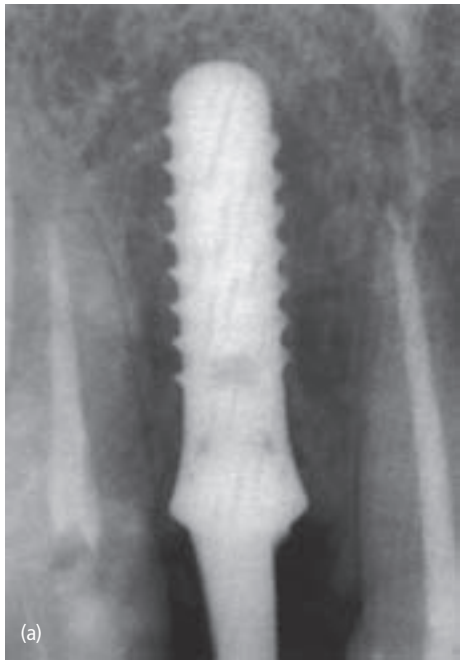
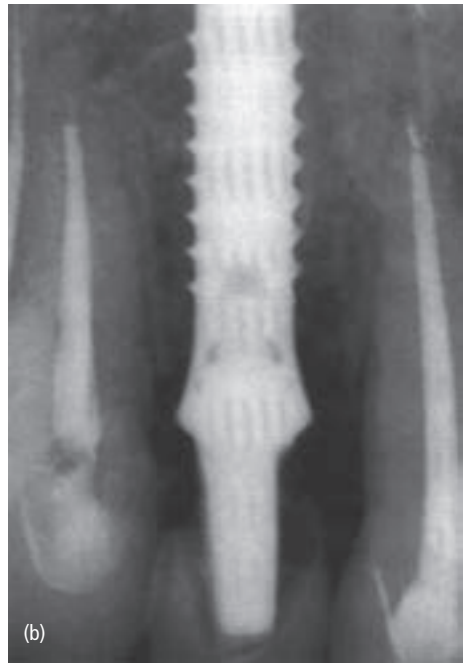
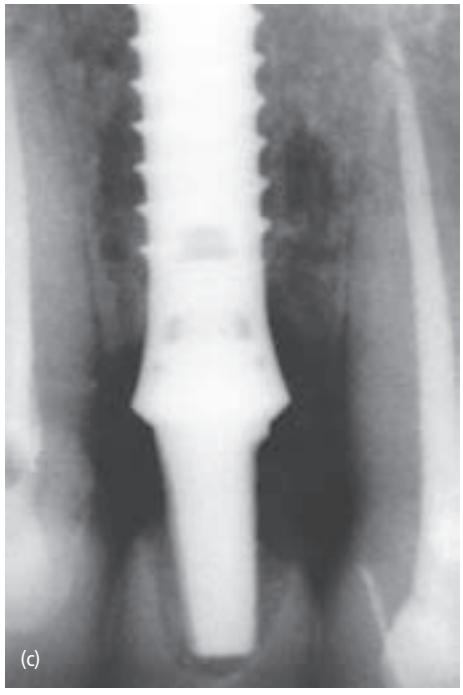
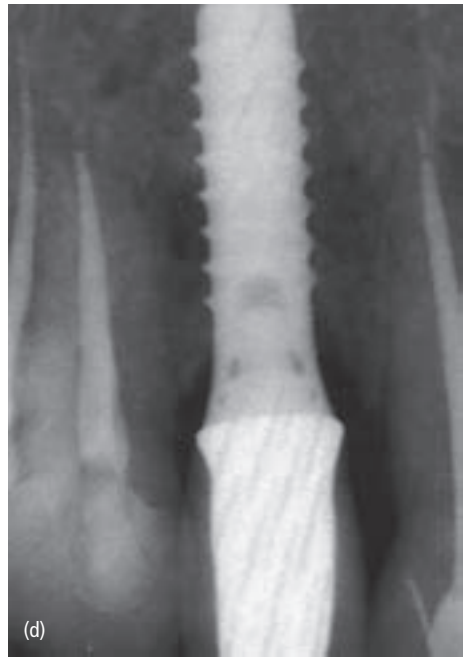


Fig. 20.3 Large circumferential defect created by removal of the fractured implant.









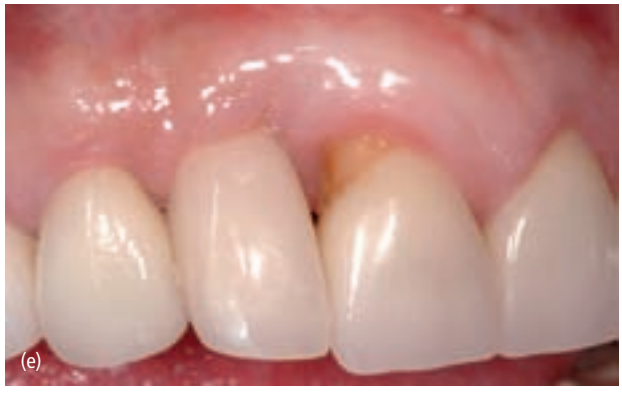


Fig. 20.4 (a) Radiograph of an immediately placed and restored implant in a maxillary lateral incisor area. Note that the implant shoulder on the mesial is placed significantly apical to the crest of bone on the distal of the central incisor. (b) Radiograph taken 3 months after placement showing significant loss of interproximal bone on the distal of the central incisor and moderate bone loss on the mesial of the canine. (c) Radiograph taken 9 months after placement showing consolidation and remodeling of the crestal bone adjacent to the implant and persistent loss of interproximal bone height on the adjacent teeth. (d) Radiograph taken 39 months after placement showing stable interproximal bone levels on the adjacent teeth compared to 9 months with re-establishment of the biologic width apical to the crown margin. Slightly increased bone loss noted on the mesial of the implant. (e) Clinical appearance 39 months after implant placement showing poor esthetics and interproximal bone loss despite several surgical attempts to repair the mesial soft-tissue defect.

increase initial stability. Figure 20.4(a–e) illustrates an example of an immediately placed and restored implant used to replace a failed maxillary lateral incisor. In review, it was apparent that the implant was placed too deeply in an attempt to optimize stability by wedging the flared implant neck into the walls of the socket. Whether this was a conscious decision by the surgeon or an inadvertent consequence of an effort to optimize stability, interproximal bone loss and poor esthetics resulted. Moreover, gradual loss of attachment on the distal of the central incisor can be seen in the serial radiographs.

The observation that surgeons tend to seat implants more apically when immediately loading is not limited to the case illustrated. In a prospective, multicenter study comparing immediately loaded posterior implants with early loaded implants, Ganeles *et al.* (60) noted that the immediately loaded implants were placed a mean of 0.3 mm deeper than the early load implants. The explanation for this finding was that the surgeons knew which implants were going to be immediately loaded, and therefore seated them more apically in order to establish additional initial stability. In essence, they tended to compromise vertical implant position, whether consciously or not, towards deeper placement in the immediately restored group. The results for successful integration and bone-level stability for the two groups did not otherwise differ significantly.

Prevention

As with other complications, it is imperative that implants be placed in correct 3D position regardless of the planned loading protocol. Implant size and depth should not be altered from ideal in order to increase initial stability. A surgical guide should be used to determine ideal apicocoronal placement (which in most cases should not be more than 3 mm apical to the buccal gingival margin).

Treatment

If adequate stability cannot be achieved, then an alternative treatment plan should be used. The implant should be allowed to heal unloaded or unrestored.

Complications associated with immediate loading in conjunction with sinus augmentation

Etiology

Often, when maxillary posterior implants are placed in areas of limited bone, a localized vertical augmentation with a bone-added osteotome (BAO) technique is used. While there are no randomized controlled studies available correlating immediate loading and simultaneous sinus augmentation, there are some limited data to suggest that implants placed using this technique may be at greater risk for failure when initial stability is reduced by limited alveolar height (61). This was reported by Levine *et al.* (62) in a delayed loading protocol in which survival rates for implants were between 96% and 99%, except where they were inserted in conjunction with BAO techniques. In the latter cases, higher failure rates were observed and the authors speculated that this was caused by the reduced initial stability. Other reasons may include delayed healing as a result of bone compression (47, 48). It would follow that immediately loading implants placed with BAO techniques would be at greater risk for failure and should be avoided. Similarly, immediate loading of implants placed with excessive bone condensation should also be avoided since prolonged healing time can be expected.

Prevention

The loss of maxillary posterior implants placed with BAO can be prevented by not using an immediate loading protocol in these cases. Other alternatives should be considered, such as delayed loading or use of cantilevered restorations.

Systemic complications: frequency unknown

There is no published information relating to specific complications from immediate loading with systemic conditions or local pathology. Most authors eliminate patients with parafunctional habits or bruxism from these studies, so there is no evidence available as to how these factors may influence immediate loading. Romanos and Nentwig (51) published a small study of nine patients who smoked heavily (more than two packs a day for at least 10 years) and received 72 implants for fixed restoration of 12 edentulous jaws and showed a success rate of 99% (71/72 implants). Other authors in anecdotal reports (36, 37) claim some limited statistical significance for the negative effect of cigarette smoking on implant success. These results should be closely evaluated by the clinician in the light of the small study sizes and lack of statistical significance.

Esthetic complications

Patients rarely lose healthy teeth in the esthetic zone and rarely have perfect alveolar ridges in which to place implants. Instead, extraction of these compromised teeth is usually accompanied by loss of hard and soft tissue. Esthetic management of dental implants placed with conventional loading protocols is generally challenging in situations where there are high demands or anatomic limitations. Site enhancement with hard- and soft-tissue

augmentation is often recommended to enhance overall success (63–65). These procedures may be used to repair existing tissue defects or to augment tissues in anticipation of future recession or resorptive tendencies.

Published esthetic complications for immediately loaded implants are rare. Most studies that evaluate esthetic outcomes of immediately loaded implants fail to differentiate between gingival contours or esthetic scores of immediately restored implants compared to similarly located implants placed under different loading protocols. Therefore, the same considerations should be included in a decision to use immediate versus delayed loading protocols in the esthetic zone.

Resorption of facial bone after extraction

Etiology

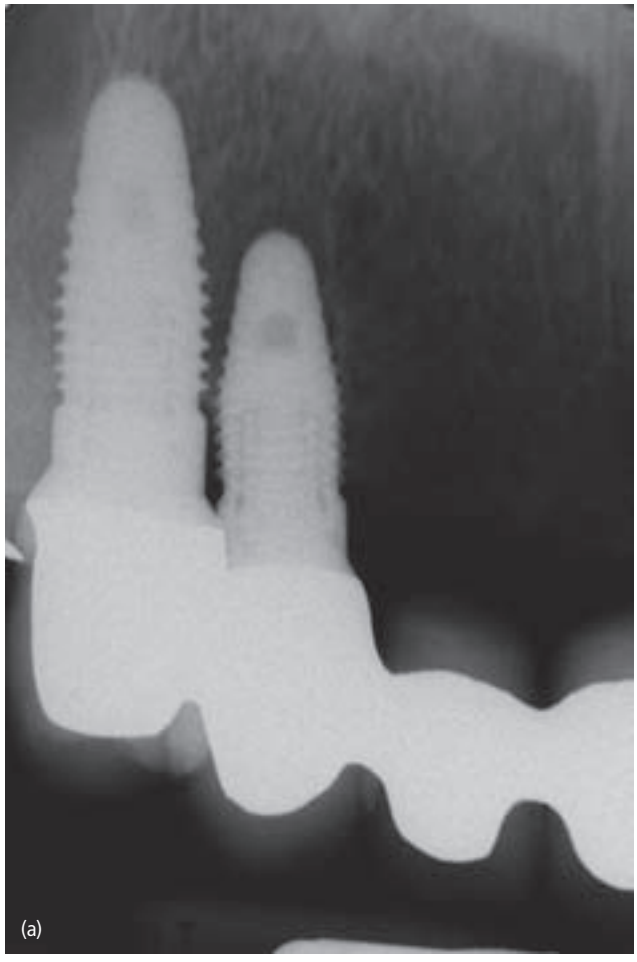
Implant placement does not prevent alveolar resorption after tooth extraction (66), which is particularly critical in the esthetic zone. An extreme example of this can be seen in Fig. 20.5(a, b), which shows an immediately placed and loaded implant approximately 7 years after surgery. While clinically immobile and functioning as an abutment for the fixed partial denture, the entire facial surface of the implant is dehisced of bone. At the time of flapless placement, the implant was contained within the socket walls. Resorption that occurred after implant restoration resulted in the apparent bony dehiscence and esthetic problem seen in Fig. 20.5(b).

Gingival recession, blunted papillae, and incomplete regeneration

Etiology

Kan *et al.* (41) reported good gingival marginal stability of immediately restored single tooth implants in the esthetic zone with few alterations after 1 year. Other authors (67, 68) indicated that limited recession often occurs which could measure as much as 1.5 mm in some cases (69). Kan *et al.* (70) suggested a correlation between the size and shape of the socket defects and final esthetic outcomes. They noted that larger initial defects produced final results with greater soft-tissue changes and poorer esthetic results.

Numerous publications indicate that good esthetic results and dimensionally stable tissues can be obtained when implants are immediately placed and restored in healed ridges. Moreover, it should be noted that there



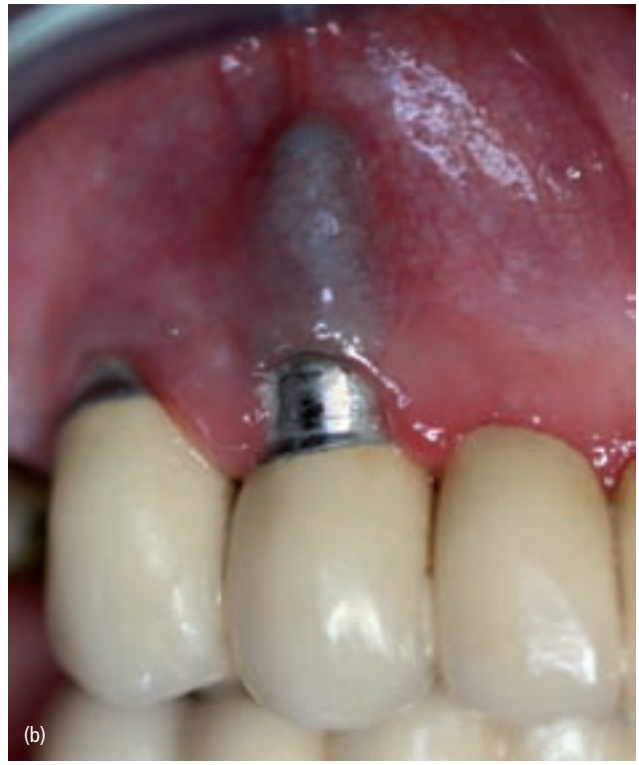
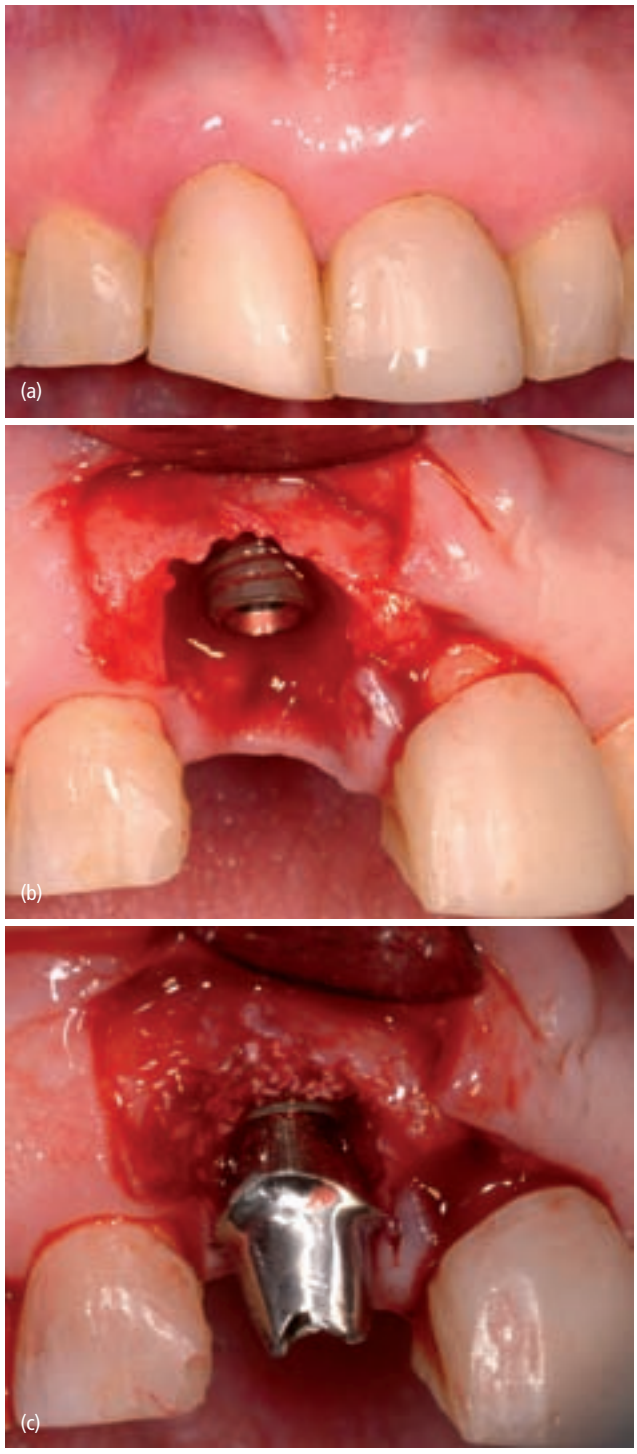


Fig. 20.5 (a, b) Seven-year radiographic and clinical appearance of an immediately placed and loaded implant in a canine area in a patient with a thin biotype with extensive facial resorption.

are no publications evaluating simultaneous augmentation or site development with immediate restorations. Kan *et al.* (70) noted a trend linking worsening esthetic outcomes with increasingly severe preoperative bony defects. Prudent practice would suggest that immediate restorations may not be compatible with significant alveolar site development, when bone and soft-tissue grafting is needed. Figure 20.6(a–f) illustrates a case of compromised esthetic results due to the fact that the



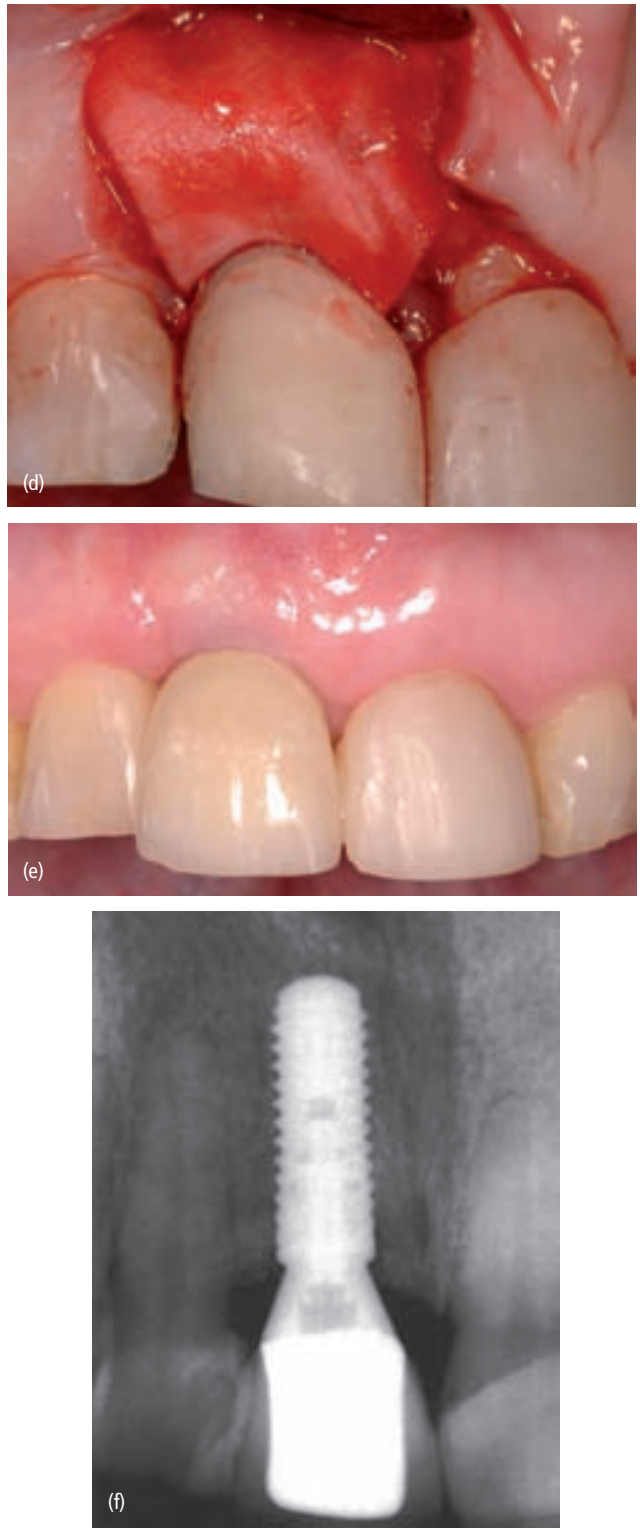


Fig. 20.6 (a) Preoperative clinical appearance of a patient with a fractured right central incisor. (b) Surgical view of implant placement with residual bony defect. (c) Grafted bony defect and contoured abutment. (d) Resorbable membrane covering defect after provisional restoration was placed. (e) Nine-month postoperative appearance showing short distal papilla compared to pretreatment appearance. (f) Nine-month postoperative radiograph showing excellent maintenance of interproximal crestal bone adjacent to the implant despite mediocre clinical appearance.

implant was immediately restored (see Chapter 18). This immediate loading protocol eliminated the opportunity to submerge the implant and correct the hard- and soft-tissue defects and maintain or regenerate the distal papilla. For some patients with low esthetic demands, this may be an acceptable result and a reasonable trade-off between optimal esthetics and reduced treatment time. However, in demanding patients and conditions, immediate restorations may increase the incidence of poor esthetic results.

Prevention

If significant augmentation is required and there is pre-existing bone loss, a staged or submerged healing protocol offers the best opportunity to maximize regenerative and esthetic outcomes before implant placement.

Recommendation

If the risk of compromised esthetic results is acceptable, then simultaneous hard- and soft-tissue augmentation may be performed at the same time as implant placement and restoration. In cases with greater esthetic demands (e.g. high lipline or multiple adjacent missing teeth) a delayed implant placement protocol following augmentations should be considered.

Implant malposition

Limited opportunity for site development influences site selection

Etiology

With immediate loading protocols the opportunities to graft or perform simultaneous site development procedures are limited since the existing available bone limits implant positioning options. As a result, in many cases implants have to be placed in the most desirable anatomic sites rather than the most desirable restoratively determined sites. These compromises alter treatment in two ways, affecting the sites selected for use in immediately loaded cases and the position of the implant within the sites. Figure 20.7(a–d) shows the case of a patient who retained his failing maxillary fixed prosthesis until it fell out of his mouth. The panorex radiograph clearly shows large periapical radiolucencies associated with many of his failing teeth, including several prosthetically strategic sites such as the canine and lateral incisor areas. Also note the moderate pneumatization of the maxillary alveolar ridges affecting the quantity of available bone in the molar sites.

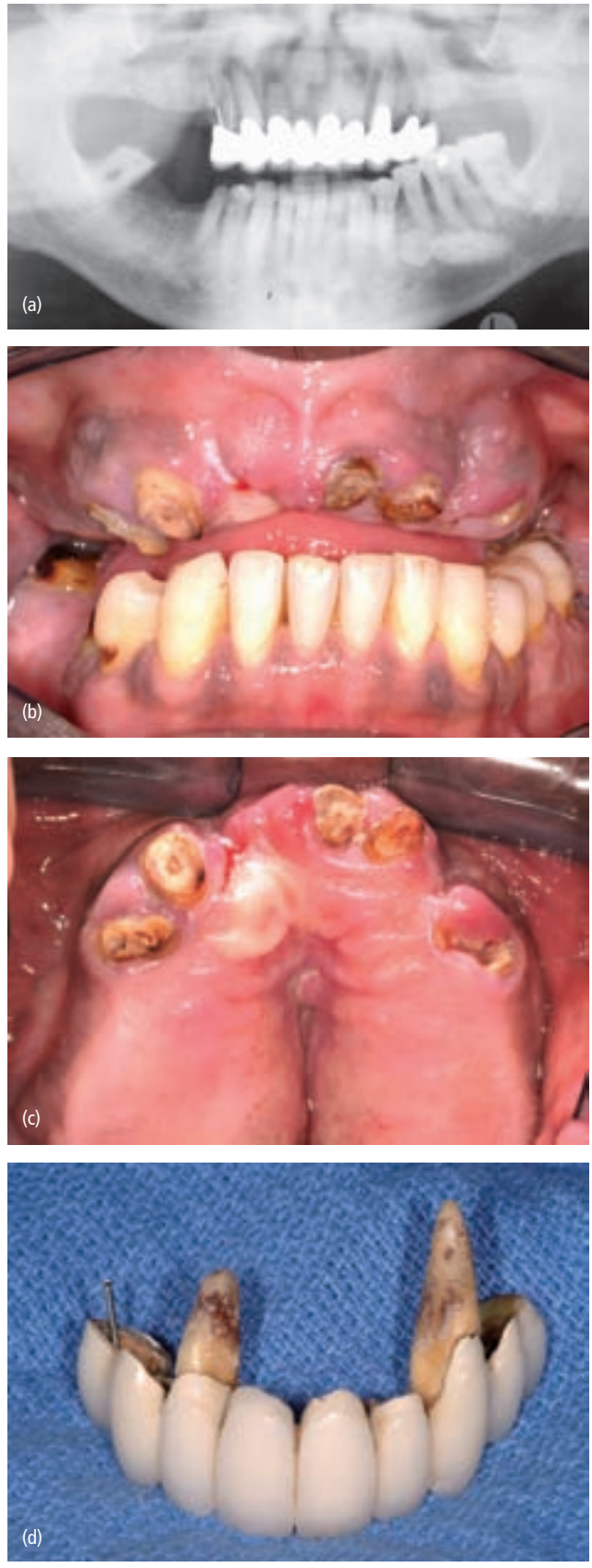
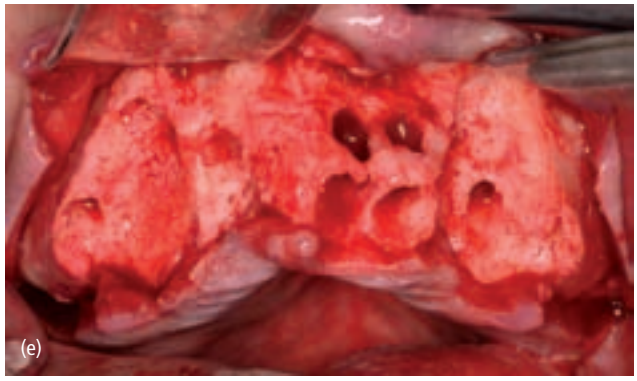
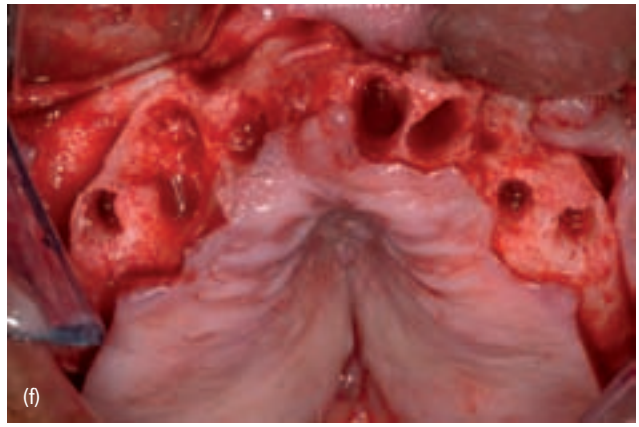
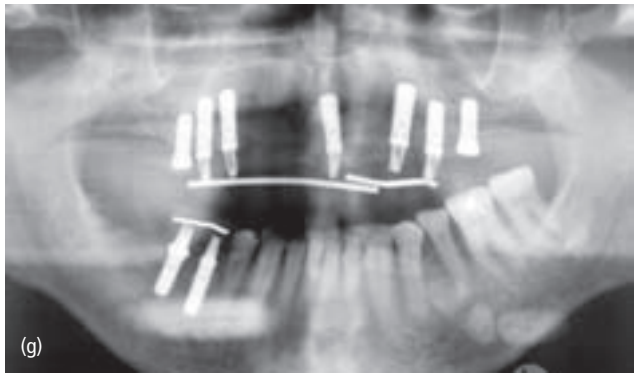
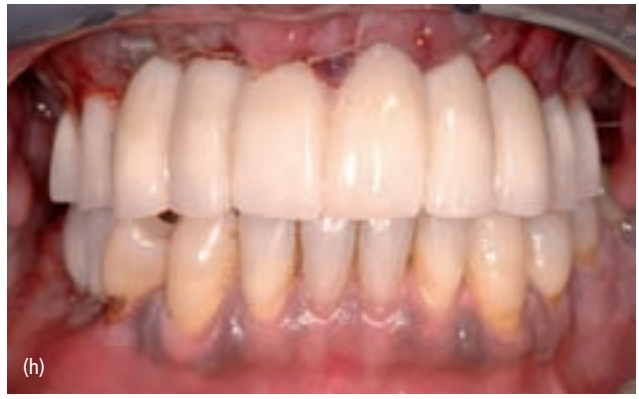


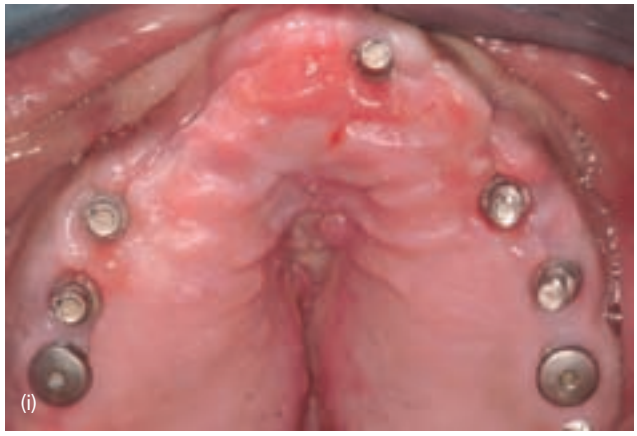
Fig. 20.7 (a) Pretreatment panoramic radiograph showing failing maxillary fixed restoration. (b–d) Clinical presentation on the day of surgery.











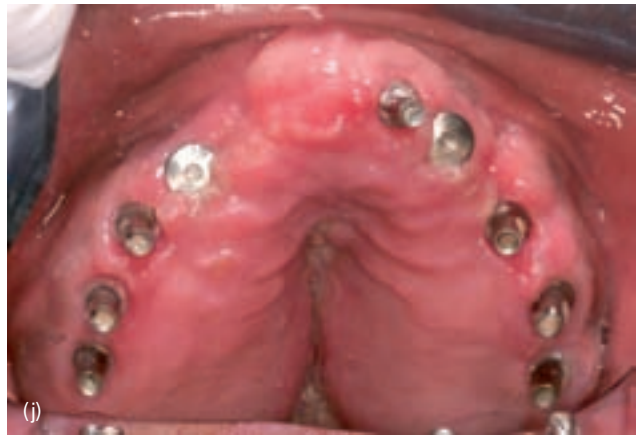


Fig. 20.7 ***(cont'd)*** (e) Facial view of the maxilla after extraction of remaining roots and thorough débridement. (f) Occlusal view of the débrided maxilla with extensive defects. (g) Immediate postoperative panoramic radiograph showing distribution of maxillary implants. Note two implants in molar areas not loaded and angled abutments in others. Metal-reinforced provisional restorations are seen in the maxillary arch and lower right. Maxillary anterior edentulous areas were grafted for future implant placement. (h) Immediate laboratory-processed provisional restoration restoring esthetics and immediate function. (i) Occlusal view of the maxilla 2 months after surgery at the time of provisional restoration removal showing distribution of loaded and unloaded implants during the initial surgery. (j) Occlusal view showing final distribution of implants after additional placement in the canine areas after healing of the grafted sites.

Optimal planning for this case called for implant placement in the canine and molar sites. However, the patient's large bony defects (Fig. 20.7e, f) and limited posterior alveolar ridge height did not permit their immediate placement or use. Instead, grafting procedures including ridge augmentation anteriorly and BAO posteriorly were performed to allow for future implant placement (Fig. 20.7g). The patient's requirement for an immediate esthetic fixed provisional restoration prevented any attempt at anterior vertical ridge augmentation necessitating long clinical crowns (Fig. 20.7h). The patient's desire for an immediate fixed restoration dictated that alternative sites be used, resulting in compromised implant distribution (Fig. 20.7i). Following healing of the augmented sites, additional implants were placed in the canine areas and the molar implants were loaded,

providing a more optimal distribution for the final restoration (Fig. 20.7j). It can be argued that ultimately the patient received additional implant(s) and prolonged treatment owing to the need for multiple surgical encounters. Conversely, it is clear that the patient benefited by remaining in fixed restorations throughout the treatment process, avoiding the potential complications and disadvantages of a complete denture.

Altered angulation to improve implant stability

Etiology

The demands of immediate loading also affect the positioning of implants within a particular site. Figure 20.8(a) illustrates the ideal implant position for a maxillary anterior tooth, centering the implant below the anatomic crown of the tooth to be replaced. In this case, the restoration could be screw retained through the cingulum or cemented using a prefabricated stock abutment available from the implant manufacturer. However, because the anterior maxilla often exhibits apical undercuts, there is an increased risk that the apex of the implant will perforate through the buccal plate. This reduces initial stability and creates additional surgical complications. The use of tapered implant designs in areas with anterior undercuts or flared ridges reduces the risk of apical fenestrations.

Figure 20.8(b) illustrates the implant positioned for optimal initial stability within the alveolar housing. The apex has been moved palatally, resulting in the long axis of the implant moving facially so that it emerges through the facial surface of the tooth or planned restoration. While this can be prosthetically corrected with an angulated abutment as shown in Fig. 20.8(c), more complex and usually more expensive customized restorative components are required. These alterations of intra-alveolar implant positions tend to be more prevalent in the maxillary arch than the mandibular arch because of the different anatomy and bone resorption patterns that occur between them.

The importance of intra-alveolar implant positioning probably increases with the length of the planned restorations, flair of the maxillary alveolar ridges and degree of apical undercuts. The significance is maximized with full-arch maxillary cases, where all occlusal forces are directed into the dental implants. The use of angled abutments in these cases permits creation of parallel insertion paths for cemented, rigid one-piece restorations, which are required for successful immediate loading (Fig. 20.8d).

Many clinicians suggest screw-retained provisional restorations for maxillary fully edentulous immediately loaded cases. Most implant designs permit some correction of divergence with screw retention. However, clinical situations frequently occur with resorbed or undercut maxillae where the divergence of implants placed to maximize initial stability is so great that screw-retained restorations could not be seated in one piece (Fig. 20.8e). The dentist is then confronted with the dilemma of seating the provisional in sections, which violates the requirement for rigid splinting, jeopardizing successful

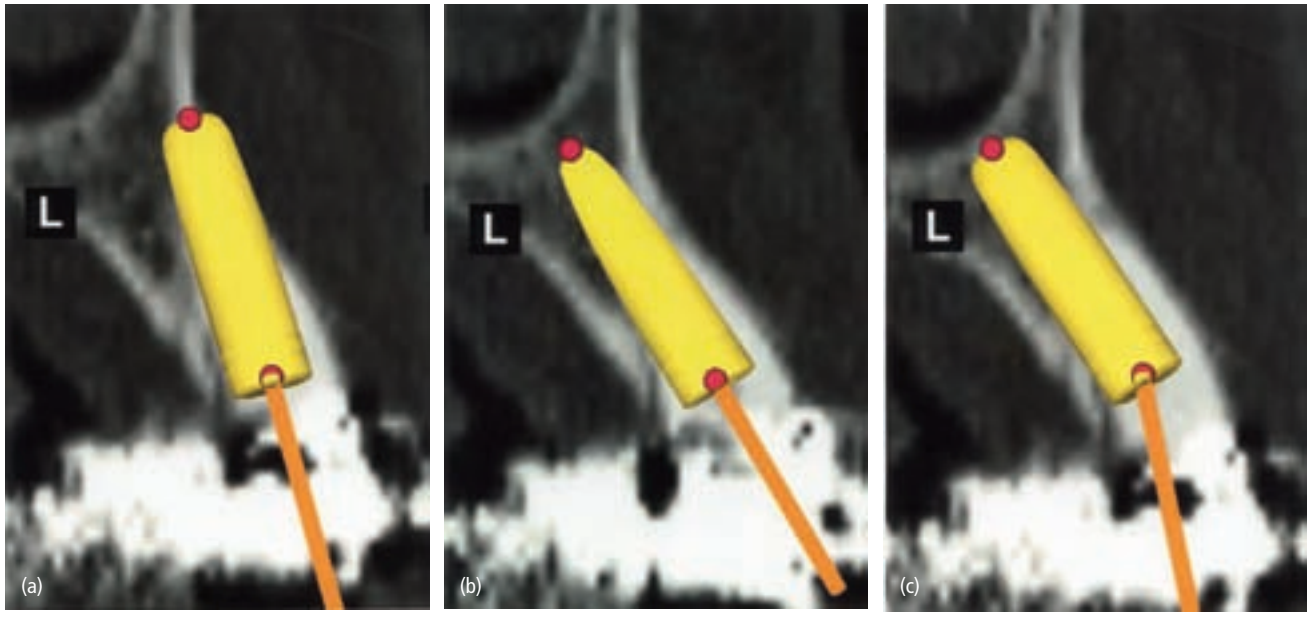
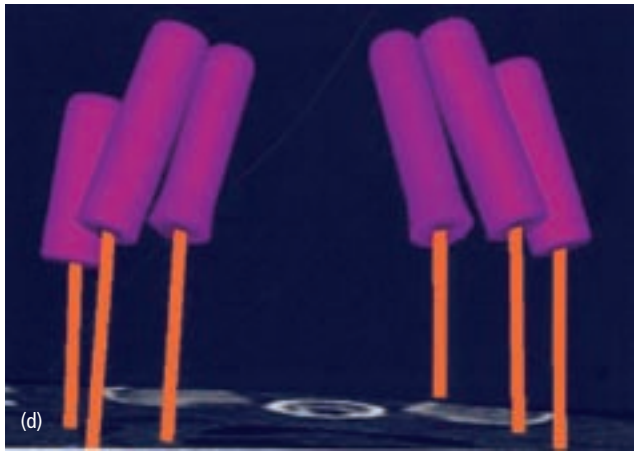
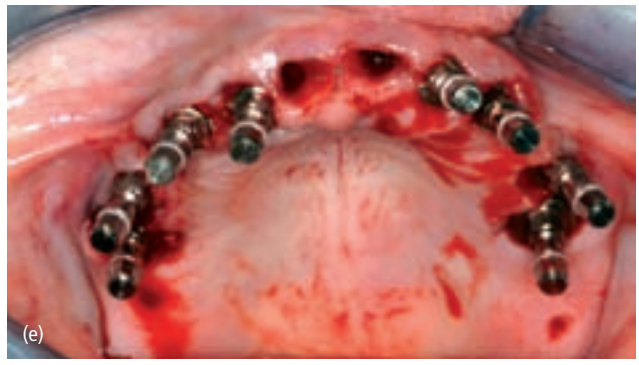
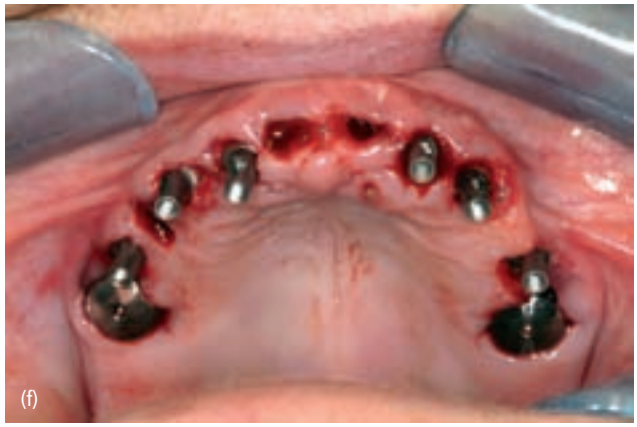
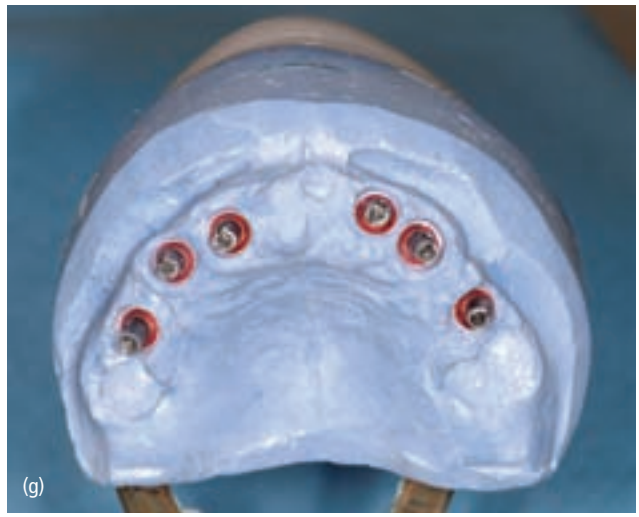


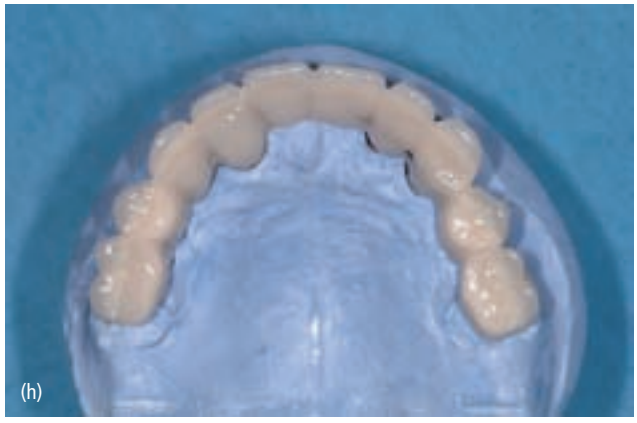
Fig. 20.8 (a) Cross-sectional maxillary radiograph with a virtual anterior implant positioned for ideal restorative position so the long axis emerges through the cingulum. Note the extensive apical fenestration that would occur with this implant position. (b) Ideal anatomic position of an implant in the same site. Note that the long axis of the implant emerges through the facial surface of the tooth. If multiple implants with this degree of facial flaring were to be used to support a restoration then some angulation compensation would be needed to correct for the significant divergence. (c) Implant in ideal anatomic position with prosthetic correction via angled abutment facilitates prosthetic parallelism.

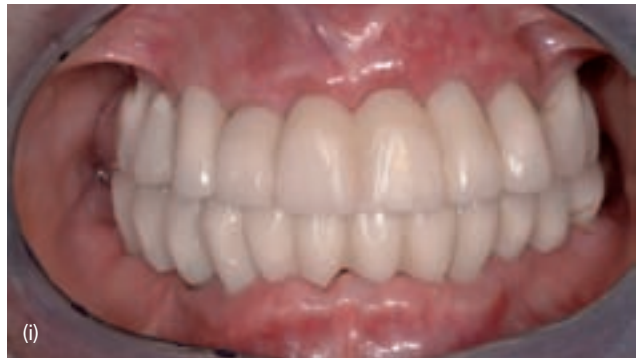












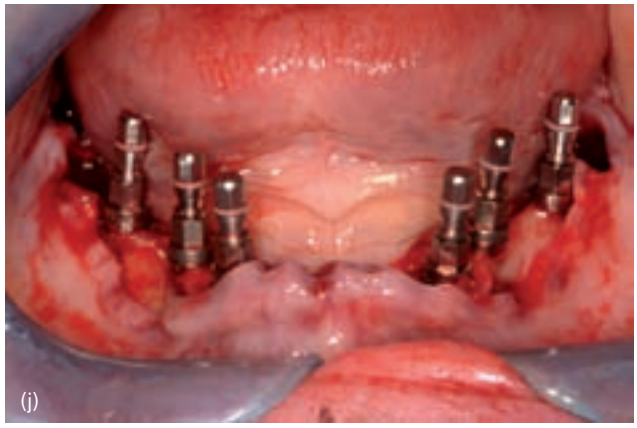


Fig. 20.8 ***(cont'd)*** (d) In cases where multiple divergent implants are used, reasonably straight paths of insertion can often be created to enable placement of rigid one-piece restorations which are necessary for immediate loading. (e) Full maxillary immediate load case with implants placed using surgical navigation to optimize implant positioning for maximum bone support. Note significant divergence of anterior and bicuspid implants. Molar implants are not planned for conventional healing and loading owing to inadequate stability. (f) Selection and placement of angled prosthetic components permit correction of significant divergence to permit fabrication and placement of cement-retained, one-piece fixed provisional restoration. (g) Cast of implants with angled abutments showing path of insertion despite significant angulation of implants. (h) Metal-reinforced, processed acrylic provisional restoration ready for insertion. (i) Cement-retained, immediately loaded full-arch provisional restorations 1 week after extractions and guided implant surgery. (j) Parallel alignment of mandibular implants is generally possible due to better bone quality and ridge form compared to maxillary arches.

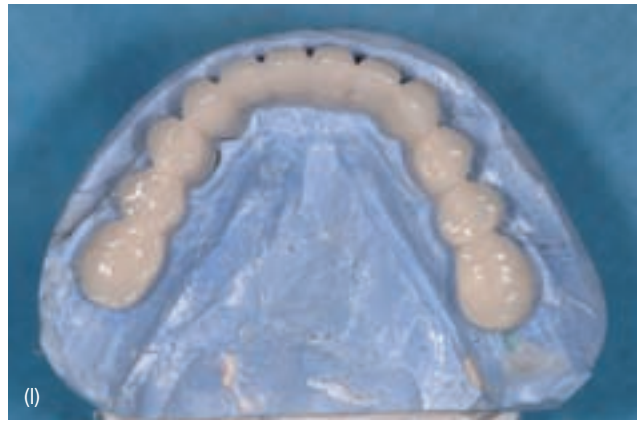


Fig. 20.8 ***(cont'd)*** (k) When implants are placed in parallel, minor discrepancies in alignment can be compensated by the built-in taper external of standard straight abutments. (l) Full-arch, laboratory-processed, metal-reinforced, cement-retained mandibular provisional restoration on cast.

osseointegration. Segments of screw-retained restorations could theoretically be joined intraorally after seating, which would leave a weakened restoration that could flex or fracture, risking successful healing. In addition, screw access holes are likely to exit the facial surfaces of anterior teeth due to the facial implant inclination, requiring inconvenient patching for esthetics.

Figure 20.8(f–i) illustrates the advantages of angle correction for implants with significant divergence in full maxillary cases. Fifteen- and twenty-degree angled abutments were strategically placed to permit a relatively parallel path of insertion. The heat-cured, laboratory-processed, metal-reinforced provisional restoration provided the rigidity, strength, and esthetic control necessary for uneventful healing. All implants integrated successfully in this case.

It should be noted that the mandibular arch was also treated at the same time in this patient using a parallel alignment protocol. In immediately loaded mandibular cases, where bone quality is generally better, intra-alveolar positioning is less critical to implant success. In the technique described by Ganeles *et al.* (71), implants can be aligned in parallel for greater prosthetic simplicity and convenience (Fig. 20.8j–l).

The concerns with intra-alveolar angulation in fully edentulous maxillary cases should be contrasted with single-unit or partially edentulous cases, where the implant-supported segments are typically protected from direct occlusal loading by adjacent natural teeth or fixed restorations. Unpublished data from a large series of full-arch maxillary immediate loading cases suggest that early failure rates for implants placed with restoratively optimized (parallel) positions (Fig. 20.8a, j) exceeded 20%. When the implant positioning strategy was changed by the same group to the anatomically optimized approach (Fig. 20.8b–e) with no other modifications, early failure rates dropped below 3%.

Recommendations

Since initial implant stability and avoidance of macromotion are the primary factors influencing successful osseointegration with immediately loaded implants, site selection is crucial when evaluating available anatomy. This assumes that the patient has adequate existing bone of sufficient quality to receive an implant in the proposed sites. As cases are planned, implants should be positioned within these sites to maximize stability and support, which often compromises angulation from the restorative perspective. Consideration should be given to ensure that this compromised site selection and/or angulation will not unduly reduce the restorative outcome, recognizing that there could be increased complexity and costs for components. These factors should be discussed and planned by the surgeon or dentist restoring the case before implant placement. If the analysis determines that the outcome of the immediately loaded plan is inferior or unacceptable, then conventional loading protocols and site development options should be considered, thus creating more flexibility in site selection and positioning.

Restorative complications

Final restorations

Restorative complications can be categorized into those relating to the provisional restorations and those of the final restorations (see Chapters 9 and 10). Final restorations may be affected by site selection and requirements for stability that affect angulation, as noted above. These factors may increase the need for custom abutments or altered restorative designs if implants are not distributed ideally (see Chapters 9 and 10). Fortunately, implant angulation does not appear to affect long-term osseo-

integration of implants, although it may predispose the final case to prosthetic complications such as restorative material failure, screw loosening, or component fracture or failures (72, 73).

Provisional restorations: occlusal mismanagement

Etiology

Complications with the provisional restoration can lead to implant failure. When single teeth or small segments are immediately restored, the provisional restorations are usually contoured and adjusted to avoid direct occlusal contact. This does not mean that they are shielded from all contact, since forces can still be applied from the tongue, food, cheeks, or foreign objects. If these secondary forces exceed the theoretical sum of the primary and secondary stability of the implant (Fig. 20.1), then implant macromovement and failure will occur. While few examples of this exist in the literature, anecdotal evidence abounds. In an unpublished series of 218 single-tooth implants placed in 211 patients, a single practitioner achieved a success rate of 96.3%, which is consistent with most published reports. However, according to the clinician, three of 27 or about 10% of the small-diameter implants failed. A similar trend was noted with partially edentulous, multiple tooth gap cases where a disproportionate number of small-diameter implants, particularly in the mandibular incisor area, failed. While these are not statistically valid samples, they are suggestive that implants with reduced surface area, subject to forces of the tongue, may be at greater risk of failure due to inadequate stability.

Recommendations for prevention

Figure 20.9(a–c) illustrates a method to prevent this problem. Bracing contacts from implant provisionals to stable adjacent teeth can be added to limit mobility from non-occlusal forces. These "wings" should be constructed to reduce the ability of the tongue to produce horizontal forces on provisional restorations, but do not need to be visible on the facial surfaces. The extensions should be smooth and unobtrusive to avoid creating an irritant which could paradoxically trigger increased tongue activity.

Treatment

If immediately restored implants are found to be mobile within a short time after placement, it may be possible to save them by eliminating or minimizing forces on them. This can be done by carefully removing the provisional restoration and abutment. If the provisional cannot be removed, then bonding the mobile implant to a stable adjacent tooth may provide sufficient stability to allow the implant to osseointegrate. A follow-up radiograph and clinical evaluation should be done approximately 1 month later to determine the prognosis. If the implant has no mobility, it should be monitored for an additional 1–2 months before final restoration. If it is mobile, it should be removed. This treatment, in the author's experience, has only been successful when mobility was

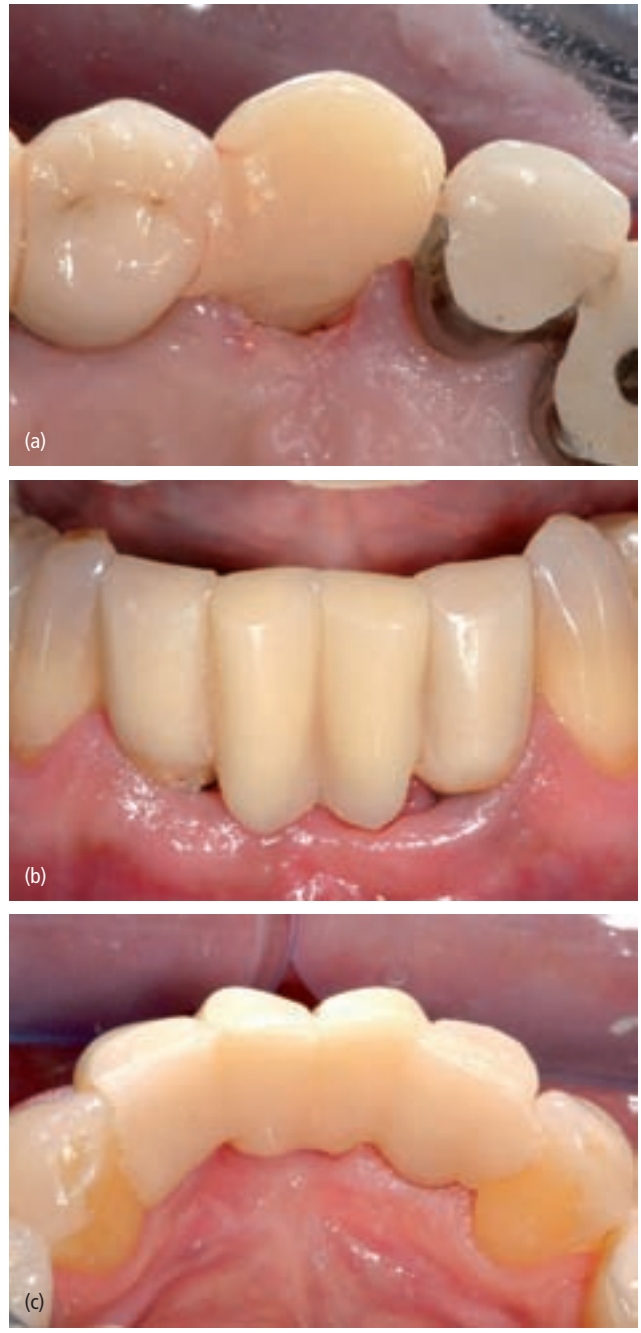


Fig. 20.9 (a) Bracing contact extended from an immediately restored maxillary canine to an adjacent implant-crown to prevent labial movement from inadvertent loading from a food bolus. (b, c) Bracing contacts extended from the distal surfaces of immediately restored mandibular lateral incisors to prevent labial displacement from the tongue.

noticed and splinting was performed within 2–4 weeks of implant placement and loading.

Provisional restorations: inadequate support, improper design, loss of retention

Etiology

In full-arch immediate loading cases, the provisional restoration must be designed to manage direct occlusal forces in addition to splinting implants and limiting mobility. Provisional restorations should be rigid and strong, and remain attached to the implants throughout the healing process (71), according to Tarnow *et al.* (34). Many techniques are available to produce and attach these provisional restorations successfully. If a provisional loosens from the supporting implants too early in the healing process or if the implant support and restoration are inadequately engineered, implant failure may occur. Figure 20.10(a–c) illustrates a failed case that was improperly planned and performed. Errors included an insufficient number and poor distribution of implants with incorporation of mobile teeth into the restoration. In addition, the restoration lost retention soon after placement, rocking the remaining abutments. There was also an inadequate distribution of occlusal forces from a lack of posterior support, even though the opposing maxillary arch was restored with a complete denture.

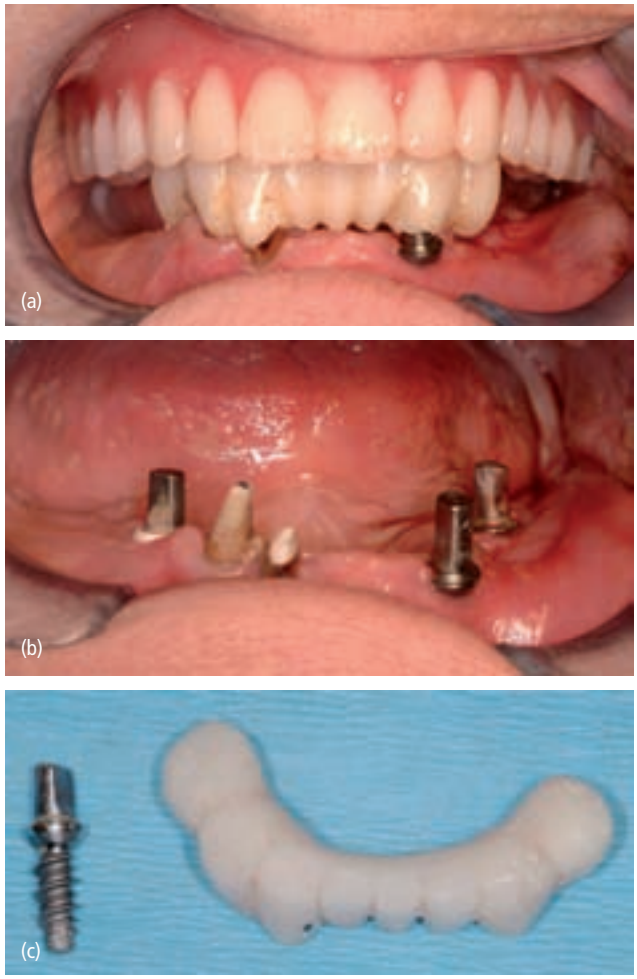


Fig. 20.10 (a–c) Failed mandibular immediately loaded case exhibiting errors of inadequate support, inadequate retention, poor margins, inadequate occlusal management, and generally poor execution.

Provisional restorations: material failure

Etiology

While Fig. 20.10(a, b) represents apparent judgment and execution errors, material failures can have the same effect on outcome. Figure 20.11(a) shows an immediate loaded case performed to replace maxillary and mandibular teeth in a patient with severe caries and bruxism. All teeth were extracted and implants were placed in both arches. Only four maxillary implants were immediately loaded due to limited stability in some of the extraction sockets. Laboratory-processed, metal-reinforced, provisional restorations were immediately placed. The patient's occlusion was designed with a relatively flat anterior group disocclusion without posterior balancing contacts, associated with periodontal–prosthetic reconstructions (74). Since the patient traveled a long distance, he was not carefully monitored during the early postoperative phase and was first seen 9 weeks after implant placement (Fig. 20.11b). At that time, it was noted that the mandibular canine teeth were fractured from the provisional restoration, creating posterior non-working interferences generating excessive lateral forces on the maxillary implants. This presumably occurred as a result of provisional material failure caused by bruxism. Therefore, all of the loaded maxillary implants failed, despite maintenance of rigidity and retention of the maxillary provisional restoration. All mandibular implants healed without complication, demonstrating the increased vulnerability of maxillary implants compared to mandibular implants in immediate loading cases. Figure 20.11(c) is the panoramic radiograph taken at the 9-week evaluation when the loaded maxillary implants were noted to have radiolucencies. All mandibular implants and unloaded maxillary implants healed normally.

Recommendations for prevention

In the above case, different options should have been considered for the maxillary arch to avoid the need to replace several failed implants. Ideally, more implants should have been loaded in the maxilla to support the restoration. If this was not possible, then alternatives including provisionalizing with a complete denture or a tooth-supported fixed provisional and a staged treat-

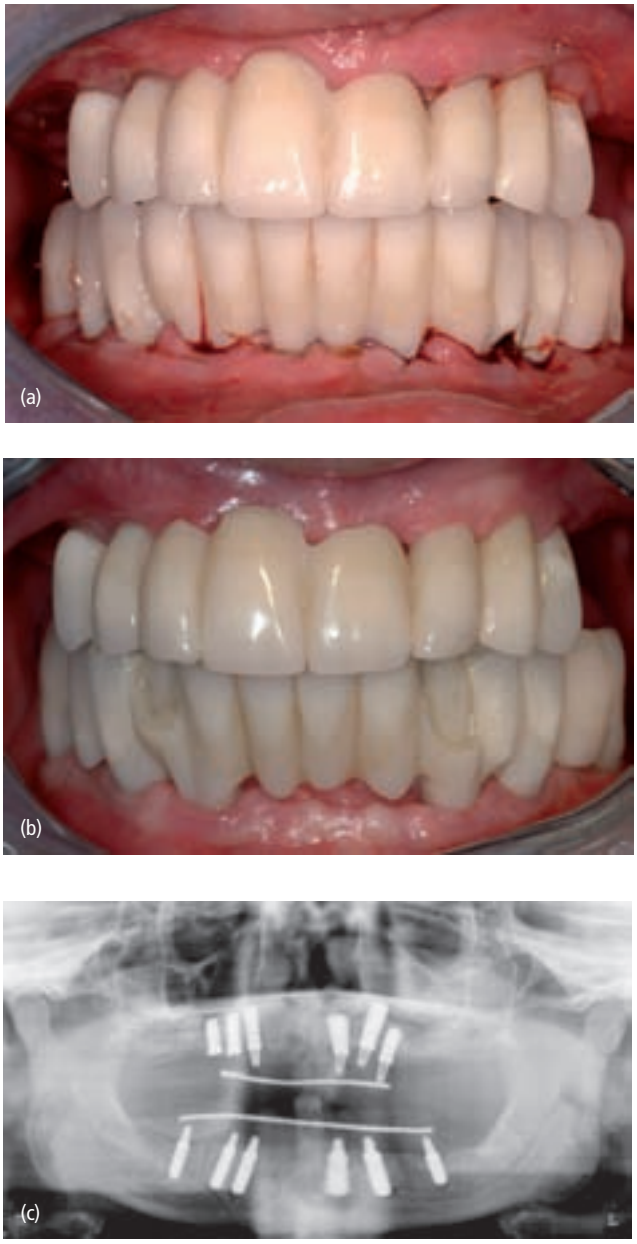


Fig. 20.11 (a) Maxillary and mandibular metal-reinforced, processed acrylic provisional restorations at the time of placement immediately postoperatively. (b, c) Clinical and radiographic appearance 9 weeks postoperatively. Note loss of mandibular canine (denture) teeth and radiolucencies around the loaded maxillary implants. The patient's bruxism was not addressed and may have played a role in the material failure of the restoration and loss of maxillary implants through parafunction and overload.

ment protocol should have been considered. Moreover, the patient's bruxing habit should have been considered when treatment planning the case to determine the occlusal scheme, number of implants, and possible need for an occlusal guard. More frequent monitoring and using stronger provisional restorative materials that compensated for the occlusal load may have altered the outcome.

Guided surgery and prefabricated restorations

Newer techniques combining immediate loading with guided surgery and computer-aided design–computer-assisted manufacturing (CAD–CAM) prefabricated restorations are available today (75). Early results from Komiyama *et al.* (76) suggest reduced success in terms of implant survival and increased prosthetic complications. Implant success rates of 89% in the maxilla and 83% in the mandible are lower than rates reported with other techniques. In addition, the authors report a significant number (5/29, 17%) of restorative complications with the prosthetic superstructures. The group reported that "surgical or technical complications arose in as many as 50% of the mandibular treatments". Oyama *et al.* (77) also reported on difficulties with the technique. The authors documented problems with framework fit and crestal bone loss in a maxillary case. This should be contrasted with the findings of van Steenberghe *et al.* (78), who reported virtually no complications for 50 consecutively treated full maxillary arches. Since the "teeth in one visit" techniques incorporate immediate loading, computerized imaging, planning, image guidance, and CAD–CAM manufacturing, there are many possible opportunities for errors, distortion, or inaccuracies. Because these systems are technique sensitive, operator error, experience, and expertise may also be factors in predictability. This combination of technologies makes identification of specific negative influencing factors difficult. However, the following complications have been reported.

Inaccurate seating of surgical template

Etiology

The fabrication and design of the template and prosthesis require a well-fitting denture that is scanned as part of the planning process. The importance of the quality, design, and fit of this denture cannot be underestimated. Errors in the denture will be transferred to both the surgical template and immediate prosthesis.

Another possible cause of misfit of the template is due to changes in the anatomy after extraction of teeth and resultant changes in the shape of the alveolus. The delay in time after extraction before impressions for the prosthesis to be scanned is important. This will depend on the number of teeth that are extracted, the reason for extraction, and the anatomy of the jaw and alveolus. Errors in fit may also occur from unfavorable ridge anatomy and hyperplastic or thick soft tissue ("flabby ridge").

The positioning of the surgical template is normally registered against the opposing jaw by having the patient bite into the correct position before being fixed with the

transverse locking pins (Fig. 20.12). Errors may occur if the opposing arch has an unstable full denture or if the patient is being treated under general anesthesia, leading to improper or imprecise centric closure.

Prevention

If the prosthesis to be scanned is inaccurate it should be remade, ensuring correct tooth position and fit. Adequate healing time after extractions should be allowed before taking impressions for planning. In addition, the length of time should be as short as possible between treatment planning and implant placement. Errors in seating of the template and adjusting occlusion may be minimized in patients undergoing sedation if evaluated when they are in a conscious state.

Fracture of the surgical template

Etiology

Significant strain and force can be applied to the surgical template during manipulation and use in surgery. It may crack or fracture if errors occur in template design or manufacture. If implants are in close proximity then the drilling sleeves may be too close, thus weakening the template structure and predisposing it to fracture. It is also possible to break the template if excessive force is used when removing the template after fixture installation.

Prevention

Ensure that there is adequate template thickness of acrylic, especially at sites where implants are in close proximity. Following implant placement careful removal of the implant mounts is required to prevent fracture of the template. In some cases all implant mounts should be loosened simultaneously if there is difficulty in removing the template.

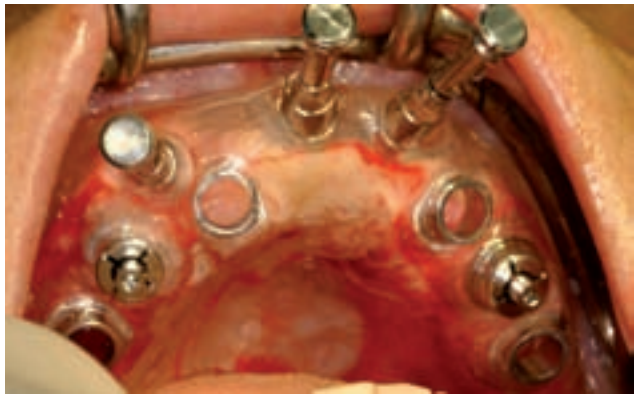


Fig. 20.12 The surgical guide must be precisely seated over the edentulous ridge, which can be problematic with flabby or redundant tissue.

Mucosal tear at the position of the anchor pins

Etiology

Since the surgical guides are large, it is possible to stretch the labial mucosa to the point of tearing when retracting the lip during the procedure.

Prevention

Ensure the lip is retracted correctly before placing the anchor pin and prevent excessive retraction during the procedure. Liberally lubricate the lips and internal lining of the cheeks with petroleum jelly. Suturing of the mucosa may be required after the procedure.

Inadequate interarch space for drills and handpiece

Etiology

The drills required for the "teeth in one visit" techniques are custom designed so that they incorporate the correct drill depth for the osteotomy and also the height of the surgical template. For this reason they are longer than conventional drills. When the drill is inserted through the occlusal surface of the template, adequate interarch space is required. This is particularly relevant when placing posterior implants or in patients who have limited jaw opening with an intact opposing dentition. Implants will often be misangulated or malpositioned because of this problem.

Prevention

Careful assessment and measurement of interarch space are necessary as part of the diagnosis and planning process. Implant positioning may need to be adjusted if there is insufficient space. Patient opening with simulated drill positioning should be performed at a separate visit before the day of surgery to determine whether there is a problem.

Incorrect implant positioning

Etiology

Errors in the planning process can result in a template that is designed with incorrectly positioned drill guides.

Prevention

Use of these computer-guided systems requires more experience, skill, and proper training in the specific system being used.

Inaccurate seating of the template

Etiology

The planning protocol needs to be strictly adhered to and the fit of the template needs to be checked before the implant placement procedure. Operator experience and assessment during the surgical procedure are required. As this procedure is normally carried out without elevating buccal or lingual flaps it is difficult to check implant positioning. If one implant is incorrectly positioned then it is likely that there was a planning problem and the template should be removed and not used during the procedure.

Prevention and treatment

Reflection of flaps to gain access for better visualization may be required. The clinician should consider having a back-up template available with the patient's understanding that a conventional unloaded protocol may be necessary with the complete denture relined and used as a provisional.

Incomplete seating of the immediate prosthesis

Etiology

As this is a flapless procedure it is necessary to use a tissue punch before preparing the osteotomies. Once the implant has been placed, visualization of the top of the implant is often not possible and there is a risk that soft-tissue tags may prevent correct seating of the prosthesis (Fig. 20.13). Impingement of these tags when seating the prosthesis may result in soft-tissue necrosis and result in fistula formation and prosthesis loosening. The correct occlusal–apical position of the implant should be evaluated radiographically since the level of the implant in relation to the crest is difficult to see clinically.

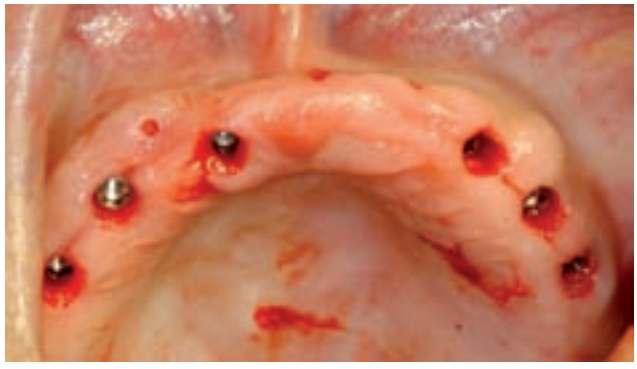


Fig. 20.13 Soft-tissue tags remaining after removal of the template, before placing the prosthesis.

Prevention

Following implant placement, repeated use of a slightly wider tissue punch is recommended to permit direct visualization of the implant head. This increases the risk of reducing the amount of attached keratinized gingiva, especially on the labial surfaces of implants in the mandibular arch.

The observation that the occlusion is significantly unbalanced should be considered a sign of possible incomplete seating of the abutments caused by soft-tissue entrapment or bone fragments between the abutment and implant. Abutment and prosthesis seating should be verified radiographically before beginning extensive occlusal adjustments or dismissing the patient.

Extensive occlusal adjustment

Etiology

While minor occlusal adjustment is considered normal in immediate implant guided restorations, extensive occlusal adjustment has been shown to be necessary in 10% of cases (76). If the implants have been threaded to proper depth, this complication is normally caused by incorrect occlusal registration during planning.

Prevention

There may be two general explanations for this problem. The first is related to surgical errors of incomplete seating of the implants or obstructed seating of the abutments to the implant, as previously noted. Removal of soft-tissue tags before seating of the abutments is often necessary. The second reason may be the result of errors in recording the correct maxillary–mandibular relationship (MMR) during the planning stage and can be avoided by repeated preoperative assessment of the MMR and careful articulation of the provisional prosthesis.

Adjustment to the tissue-fitting surface of the prosthesis

Etiology

This is a complication that is difficult to avoid. The thickness of the mucosa is difficult to assess on radiographs. As a result the amount of contact pressure between the soft tissue and prosthesis often needs to be adjusted (Fig. 20.14). If gingival thickness is underestimated, then the tissue surface of the restoration will impinge, preventing full seating until it is adequately reduced. Alternatively, if the gingival thickness is overestimated, gaps between the restoration and tissue will occur, potentially interfering with speech. Ridge lap designs

with pink restorative materials, which are often associated with these restorations, often hinder accessibility for plaque removal under the prosthesis, becoming maintenance challenges.

Prevention

Prevention of this problem is difficult and the patient must be informed before treatment of the need for adjustments after prosthesis placement. It is important to resolve this issue in the provisional restoration before fabrication of the final restoration. Communication among the patient, restorative dentist, and dental technician is important at this stage.

Loss of attached keratinized gingiva after implant placement

Etiology

This is a common complication in the edentulous mandible due to the thin zone of attached keratinized gingiva that is often present. This complication, together with active and high muscle attachments, can result in discomfort and maintenance problems. It is more common in the "teeth in one visit" technique in which a tissue punch is used before osteotomy preparation.

Prevention

Soft-tissue grafting before the surgical procedure should be considered in areas of limited keratinized tissue. The option of reflecting a buccal flap before seating of the template carries the complication of affecting the fit of the template as it is normally tissue fitting.

Radiographic bone loss around implants and implant failure

Etiology

A higher failure rate of implants with a computer-guided technique compared to conventional treatment has been reported (76). The reason for this difference is not entirely clear. Speculation about the reasons for failure is difficult in view of the lack of studies documenting complications. The differences between this technique and conventional immediate loading include the use of a rigid template and a flapless approach. In addition, a higher number of complications occurred in the mandible, where bone quality is normally denser than in the maxilla. Overheating of the bone during preparation is possible as the fixed template and flapless approach often result in reduced efficiency of drill irrigation and cooling (Fig. 20.15).

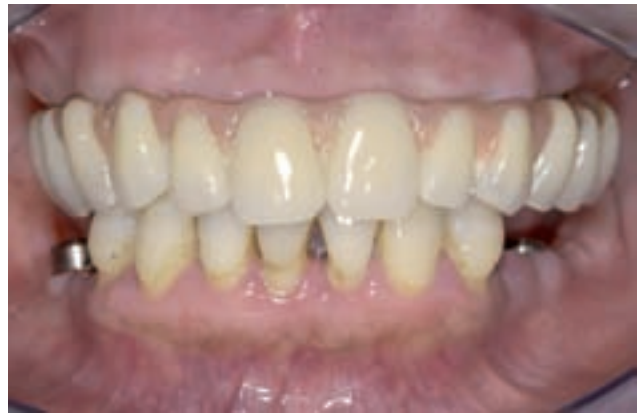


Fig. 20.14 Inaccurate fit of the prosthesis against the gingiva requires adjustment for full seating, hygiene, and lip support.

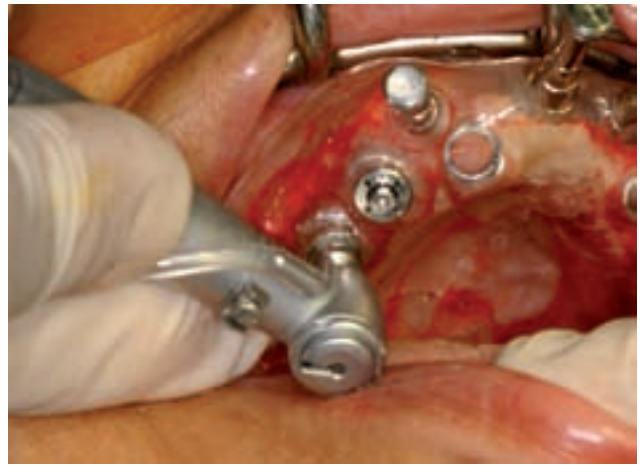


Fig. 20.15 Difficulty irrigating owing to interference from and limited coolant accessibility through the surgical guide.

Another reason could be the reduction in tactile sensation as the drill passes through the drill sleeve. This may affect operator judgment and assessment of bone quality, leading to overestimating implant stability. Guided drilling should be contrasted to conventional treatment where there is often more tactile feedback to the surgeon, who might change the drilling sequence or alter the loading plan. The lack of flexibility and inability of the clinician to change angulation, depth, and distance between implants, compared to conventional or navigated placement (79, 80), should be recognized as a practical trade-off against the benefits of sophisticated surgical guides, prefabricated restorations, and faster surgical procedures.

Prevention and treatment of failed implants

As the implant placement is accurately determined by the rigid surgical template, there is no reason why the

template cannot be reused to replace a failed implant in the same position once the bony ridge has healed after implant removal. This is possible because of the use of adjustable abutments with the provisional prosthesis. This carries a significant advantage over conventional implant placement as the provisional prosthesis does not need to be remade. If, however, the final prosthesis is in place then the accuracy of implant replacement will often be compromised. For this reason the provisional prosthesis should be left in position until integration of the fixtures is assessed.

Summary

Immediate loading of dental implants has been reported in the scientific literature by a large number of authors in a wide variety of patients and clinical conditions. The original assumption that dental implants require stress-free submerged healing has been shown to be incorrect. More detailed understanding of the wound healing of osseointegration suggests that implant movement during healing is one of the critical factors in determining the establishment of the bone to dental implant interface. It should also be recognized that implant healing occurs in phases, beginning with a reduction in stability followed by establishment of a new bone tissue deposited onto the implant surfaces. The rates of osteoclastic activity, osteoblastic activity, implant geometry, implant surface chemistry, bone activity, patient health, and applied forces dictate the timing and success of the healing process.

When patients are treatment planned for immediately loaded implants, techniques must be used that optimize and protect the stability of the implants during the healing phase. This limits site development and grafting options and often requires that implants be placed in prosthetically less desirable but anatomically advantageous positions. Sound restorative designs, strong durable materials, and meticulous techniques should be used to obtain uncomplicated healing and predictable outcomes.

Despite the published consensus that immediately loading or restoring implants is as predictable as conventional loading, dentists should be aware that the majority of the authors are highly skilled practitioners working under controlled clinical conditions with careful case selection. Opportunities for complications and failures with immediate loading are increased since the surgical and restorative aspects of treatment are combined into one treatment visit. Knowledgeable, prepared, experienced clinicians have the greatest likelihood of success with these complex treatment protocols.

Take-home hints

- When considering immediate loading, it is critically important to remember that implants must remain immobile for a long enough period to allow osseointegration to occur and that the first phases of healing include decreased implant stability.
- Complications from failure of immediately loaded implants and restorations may present major problems compared to other loading protocols because of increased patient expectations, damage to surgical sites, and the need for urgent resolution of failing treatment and prostheses.
- Implant survival statistics for immediately restored or loaded implants can be comparable to early or delayed loading protocols when appropriate case selection and methods are used.
- Surgical and restorative strategies to protect implants from movement during early healing should be employed. These techniques include using longer, wider implants and maintaining rigid provisional restorations in place until implants are healed. Implants should be placed to optimize implant support within the alveolar housing and distributed around the edentulous span, increasing anterior–posterior spacing whenever possible.
- With immediate loading conditions, provisional restorations become integral components to the healing implants, so that shortcomings of the provisionals may adversely affect osseointegration.
- Currently, there is virtually no evidence to suggest that simultaneous site development and implant loading is predictable, so that implants to be immediately loaded or restored should have adequate stability in native bone to be considered for use immediately.
- Esthetics may be compromised in strategic or highly visible sites owing to limitations for simultaneous placement, augmentation, and loading procedures.
- With immediately loaded or restored implants, site selection and alveolar position should be optimized for bone support rather than prosthetic convenience, often leading to compromised or more complicated restorations and restorative designs.
- Application of technology for diagnosis, evaluation of bone density and volume, and positional planning is strongly recommended to minimize the possibility of complications. Use of CAD/CAM restorations has not yet consistently reduced complications.

- Immediate restoration and loading should generally be considered a complex (81) procedure requiring significant clinician skill, thorough diagnosis, proper case selection, experience, patient cooperation, and advanced, meticulous techniques to minimize adverse outcomes.
- Clinicians who use immediate loading protocols should anticipate the unique challenges, compensate for the possible unfavorable effects, and be prepared to treat the potential complications discussed in this chapter.
- With proper patient selection, planning, and execution, immediate loading and restoration can provide benefits over other loading protocols, including reduced treatment time and improved patient esthetics and function during the healing process. Individualized risk assessment should be done when immediate protocols are considered.

References

1. Laney WR. *Glossary of oral and maxillofacial implants*. Berlin: Quintessence: 73–4.
2. Raghavendra S, Wood MC, Taylor TD. Early wound healing around endosseous implants: a review of the literature. *Int J Oral Maxillofac Implants* 2005; **20**: 425–431.
3. Oates TW, Valderrama P, Bischof M, Nedir R, Jones A, Simpson J, *et al.* Enhanced implant stability with a chemically modified SLA surface: a randomized pilot study. *Int J Oral Maxillofac Implants* 2007; **22**: 755–60.
4. Szmucler-Moncler S, Piatelli A, Favero GA, Dubruille JH. Considerations preliminary to the application of early and immediate loading protocols in dental implantology. *Clin Oral Implants Res* 2000; **11**: 12–5.
5. Cameron H, Pilliar RM, Macnab I. The effect of movement on the bonding of porous metal to bone. *J Bio Mater Res* 1973; **7**: 301–11.
6. Schatzker J, Horne JG, Sumner-Smith G. The effect of movement on the holding power of screws in bone. *Clin Orthodont Relat Res* 1975; **111**: 257–62.
7. Soballe K, Hansen ES, Brockstedt-Rasmussen H, Bunger C. Tissue ingrowth into titanium and hydroxyapatite-coated implants during stable and unstable mechanical conditions. *J Orthop Res* 1992; **10**: 285–99.
8. Szmukler-Moncler S, Salama H, Reingewirtz Y, Dubruille JH. Timing of loading and effect of micromotion on bone-dental implant interface: review of experimental literature. *J Biomed Mater Res* 1998; **43**: 192–203.
9. Brunski JB, Moccia AF, Pollock SR, Korostoff E, Trachtenberg DI. The influence of functional use of endosseous dental implants on the tissue implant interface: 1. Histological aspects. *J Dent Res* 1979; **58**: 1953–63.
10. Ioi H, Morishita T, Nakata S, Nakasima A, Nanda RS. Evaluation of physiologic tooth movements within clinically normal periodontal tissues by means of periodontal pulsation measurements. *J Periodontal Res* 2002; **37**: 110–17.
11. Esposito M, Grusovin MG, Coulthard P, Thomsen P, Worthington HV. A 5-year follow-up comparative analysis of the efficacy of various osseointegrated dental implant systems: a systematic review of randomized controlled clinical trials. *Int J Oral Maxillofac Implants* 2005; **20**: 557–68.
12. Lindh T, Gunne J, Tillberg A, Molin M. A meta-analysis of implants in partial edentulism. *Clin Oral Implants Res* 1998; **9**: 80–90.
13. Attard NJ, Zarb GA. Immediate and early implant loading protocols: a literature review of clinical studies. *J Prosthet Dent* 2005; **94**: 242–58.
14. Aparico C, Rangert B, Sennerby L. Immediate/early loading of dental implants. A report from the Sociedad Espaniola de Implantes World Congress Consensus Meeting in Barcelona Spain, 2002. *Clin Implant Dent Relat Res* 2003; **5**: 57–60.
15. Jokstad A, Carr A. What is the effect on outcomes of time-to-loading of a fixed or removable prosthesis placed on implant(s)? Review for the Academy of Osseointegration State of the Science of Implant Dentistry Conference 2006. *Int J Oral Maxillofac Implants* 2007; **22** (Suppl): 19–48.
16. Del Fabbro M, Testori T, Francetti L, Taschieri S, Weinstein R. Systematic review of survival rates for immediately loaded dental implants. *Int J Periodontics Restorative Dent* 2006; **26**: 249–63.
17. Ganeles J, Wismeijer D. Early and immediately restored and loaded dental implants for single-tooth and partial arch reconstructions. *Int J Oral Maxillofac Implants* 2004; **19** (Suppl): 92–102.
18. Chiapasco M. Early and immediate restoration and loading of implants in completely edentulous patients. *Int J Oral Maxillofac Implants* 2004; **19** (Suppl): 76–91.
19. Jaffin RA, Kumar A, Berman CL. Immediate loading of dental implants in the completely edentulous maxilla: a clinical report. *Int J Oral Maxillofac Implants* 2004; **19**: 721–30.
20. Achilli A, Tura F, Euwe E. Immediate/early functioning with tapered implants supporting maxillary and mandibular posterior fixed partial dentures: preliminary results of a prospective multicenter study. *J Prosthet Dent* 2007; **97**: S52–8.
21. Cannizzaro G, Leone M, Esposito M. Immediate functional loading of implants placed with flapless surgery in the edentulous maxilla: 1-year follow-up of a single cohort study. *Int J Oral Maxillofac Implants* 2007; **22**: 87–95.
22. Cannizzaro G, Leone M, Consolo U, Ferri V, Esposito M. Immediate functional loading of implants placed with flapless surgery versus conventional implants in partially edentulous patients: a 3-year randomized controlled clinical trial. *Int J Oral Maxillofac Implants* 2008; **23**: 867–75.
23. Esposito M, Grusovin MG, Willings, M, Coulthard P, Worthington, HV. The Effectiveness of immediate, early, and conventional loading of dental implants: a Cochrane Systematic Review of randomized controlled clinical trials. I*nt J Oral Maxillofac Implants* 2007; **22**: 893–904.
24. Testori T, Galli F, Capelli M, Zuffetti F, Esposito M. Immediate nonocclusal versus early loading of dental implants in partially edentulous patients: 1-year results from a multicenter, randomized controlled clinical trial. *Int J Oral Maxillofac Implants* 2007; **22**: 815–22.
25. Meyer U, Joos U, Mythili J, Stamm T, Hohoff A, Fillies T, *et al.* Ultrastructural characterization of the implant/bone

interface of immediately loaded dental implants. *Biomaterials* 2004; **25**: 1959–67.
26. Guida L, Iezzi G, Annunziata M, Salierno A, Iuorio G, Costigliola G, Piattelli A. Immediate placement and loading of dental implants: a human histologic case report. *J Periodontol* 2008; **79**: 575–81.
27. Vandamme K, Naert I, Vander Sloten J, Puers R, Duyck J. Influence of controlled immediate loading and implant design on peri-implant bone formation. *J Clin Periodontol* 2007; **34**: 172–81.
28. Davarpanah M, Caraman M, Jakubowicz-Kohen B, Kebir-Quelin M, Szmukler-Moncler S. Prosthetic success with a maxillary immediate-loading protocol in the multiple-risk patient. *Int J Periodontics Restorative Dent* 2007; **27**: 161–9.
29. Horwitz J, Zuabi O, Peled M, Machtei E. Immediate and delayed restoration of dental implants in periodontally susceptible patients: 1-year results. *Int J Oral Maxillofac Implants* 2007; **22**: 423–9.
30. Crespi R, Cappare P, Gherlone E, Romanos GE. Immediate occlusal loading of implants placed in fresh sockets after tooth extraction. *Int J Oral Maxillofac Implants* 2007; **22**: 955–62.
31. Jaffin RA, Kolesar M, Kumar A, Ishikawa S, Fiorellini J. The radiographic bone loss pattern adjacent to immediately placed, immediately loaded implants. *Int J Oral Maxillofac Implants* 2007; **22**: 187–94.
32. Schnitman PA, Wohrle PS, Rubenstein JE. Immediate fixed interim prostheses supported by two-stage threaded implants: methodology and results. *J Oral Implantol* 1990; **16**: 96–105.
33. Schnitman PA, Wohrle PS, Rubenstein JE, Da Silva JD, Wang N-H. Ten-year results for Brånemark implants immediately loaded with fixed prostheses at implant placement. *Int J Oral Maxillofac Implants* 1997; **12**: 495–503.
34. Tarnow DP, Emtiaz S, Classi A. Immediate loading of threaded implants at stage 1 surgery in edentulous arches: ten consecutive case reports with 1-to 5-year data. *Int J Oral Maxillofac Implants* 1997; **12**: 319–24.
35. Ericsson I, Nilson H, Nilner K, Randow K. Immediate functional loading of Brånemark single tooth implants: an 18 month clinical pilot follow-up study. *Clin Oral Implants Res* 2000; **11**: 26–33.
36. Rocci A, Martignoni M, Gottlow J. Immediate loading in the maxilla using flapless surgery, implant placed in predetermined positions, and prefabricated provisional restorations: a retrospective 3-year clinical study. *Clin Implant Dent Relat Res* 2003; **5** (Suppl 1): 29–36.
37. Malo P, Rangert B, Dvarsater L. Immediate function of Brånemark implants in the esthetic zone: a retrospective clinical study with 6 months to 4 years of follow-up. *Clin Implant Dent Relat Res* 2000; **2**: 138–46.
38. Rocci A, Martignoni M, Gottlow J. Immediate loading of Brånemark system TiUnite and machined surface implants in the posterior mandible: a randomized open-ended clinical trial. *Clin Implant Dent Related Res* 2003; **5** (Suppl 1): 57–63.
39. Schincaglia P, Marzola R, Scapoli C, Scotti R. Immediate loading of dental implants supporting fixed partial dentures in the posterior mandible: a randomized controlled split-mouth study – machined versus titanium oxide surface implant surface. *Int J Oral Maxillofac Implants* 2007; **22**: 35–46.
40. Chaushu G, Chaushu S, Tzohar A, Dayan D. Immediate loading of single-tooth implants: immediate versus non-immediate implantation. A clinical report. *Int J Oral Maxillofac Implants* 2001; **16**: 267–72.
41. Kan YK, Rungcharassaeng K, Lozada J. Immediate placement and provisionalization of maxillary anterior single implants: 1-year prospective study. *Int J Oral Maxillofac Implants* 2003; **18**: 31–9.
42. Vanden Bogaerde L, Pedretti G, Dellacassa P, Mozzati M, Rangert B, Wendelhag I. Early function of splinted implants in maxillas and posterior mandibles, using Brånemark System TiUnite implants: an 18-month prospective clinical multicenter study. *Clin Implant Dent Relat Res* 2004; **6**: 121–9.
43. Roccuzzo M, Wilson TG. A prospective study of 3 weeks' loading of chemically modified titanium implants in the maxillary molar region: 1-year results. *Int J Oral Maxillofac Implants* 2009; **24**: 65–72.
44. Calandriello R, Tomatis M, Rangert B. Immediate functional loading of Brånemark system implants with enhanced initial stability: a prospective 1- to 2-year clinical and radiographic study. *Clin Implant Dent Relat Res* 2003; **5** (Suppl 1): 10–20.
45. Degidi M, Piattelli A. Immediate functional and non-functional loading of dental implants: a 2- to 60-month follow-up study of 646 titanium implants. *J Periodontol* 2003; **74**: 225–41.
46. Stavropoulos A, Nuyengaard JR, Lang NP, Karring T. Immediate loading of single SLA implants: drilling vs. osteotomes for the preparation of the implant site. *Clin Oral Implants Res* 2008; **19**: 55–65.
47. Nkenke E, Lehner B, Fenner, M, Roman FS, Thams U, Neukam FW, Radespiel-Troger M. Immediate versus delayed loading of dental implants in the maxillae of minipigs: follow-up of implant stability and implant failures. *Int J Oral Maxillofac Implants* 2005; **20**: 39–47.
48. Büchter A, Kleinheinz J, Wiesmann HP, Jayaranan M, Joos U, Meyer U. Interface reaction at dental implants inserted in condensed bone. *Clin Oral Implant Res* 2005; **16**: 509–17.
49. Bashutski JD, D'Dilva NJ, Wang H-L. Implant compression necrosis: current understanding and case report. *J Periodontol* 2009; **80**: 700–4.
50. Meredith N, Alleyne D, Cawley P. Quantitative determination of the stability of implant–tissue interface using resonance frequency analysis. *Clin Oral Implants Res* 1996; **7**: 261–7.
51. Romanos GE, Nentwig G-H. Immediate loading using cross-arch fixed restorations in heavy smokers: nine consecutive case reports for edentulous arches. *Int J Oral Maxillofac Implants* 2008; **23**: 513–19.
52. Gallucci GO, Bernard J-P, Bertosa M, Belser UC. Immediate loading with fixed screw-retained provisional restorations in edentulous jaws: the pickup technique. *Int J Oral Maxillofac Implants* 2004; **19**: 524–33.
53. Cranin AN, De Grado J, Kaufman M, Baraoidan M, Di Gregorio R, Batgitis G, ZuBin L. Evaluation of the Periotest as a diagnostic tool for dental implants. *J Oral Implantol* 1998; **3**: 139–46.

54. Sennerby L, Meredith N. Implant stability measurements using resonance frequency analysis: biological and biomechanical aspects and clinical implications. *Periodontol 2000* 2008; **47**: 51–66.
55. Degidi M, Daprile G, Piattelli A. Primary stability determination: operating surgeon's perception and objective measurement. *Int J Oral Maxillofac Implants* 2010; in press.
56. Abrahamsson I, Linder E, Lang NP. Implant stability in relation to osseointegration: an experimental study in the Labrador dog. *Clin Oral Implants Res* 2009; **20**: 313–18.
57. Song Y-D, Jun S-H, Kwon J-J. Correlation between bone quality evaluated by cone-beam computerized tomography and implant primary stability. *Int J Oral Maxillofac Implants* 2009; **24**: 59–64.
58. Ormianer Z, Palti A. Long-term clinical evaluation of tapered multi-threaded implants: results and influences of potential risk factors. *J Oral Implantol* 2006; **32**: 300–7.
59. Lang NP, Tonetti MS, Suvan JE, Bernard JP, Botticelli D, Fourmousis I, *et al.* Immediate implant placement with transmucosal healing in areas of aesthetic priority. A multicentre randomized-controlled clinical trial 1. Surgical outcomes. *Clin Oral Implants Res* 2007; **18**: 188–96.
60. Ganeles J, Zollner A, Jackowski J, ten Brugenkate C, Beagle J, Guerra F. Immediate and early loading of Straumann implants with a chemically modified surface (SLActive) in the posterior mandible and maxilla: 1-year results from a prospective multicenter study. *Clin Oral Implants Res* 2008; **19**: 1119–28.
61. Rosen PS, Summers R, Mellado JR, Salkin LM, Shanaman RH, Marks MH, Fugazzotto PA. Tehbone-added osteotome sinus floor elevation technique: multicenter retrospective report of consecutively treated patients. *Int J Oral Maxillofac Implants* 1999; **14**: 853–8.
62. Levine RA, Ganeles J, Jaffin RA, Clem DS, Beagle JR, Keller GW. Multicenter retrospective analysis of wide-neck dental implants for single molar replacement. *Int J Oral Maxillofac Implants* 2007; **22**: 736–42.
63. Grunder U, Gracis S, Capelli M. Influence of the 3-D bone-to-implant relationship on esthetics. *Int J Periodontics Restorative Dent* 2005; **25**: 113–19.
64. Buser D, Martin W, Belser UC. Optimizing esthetics for implant restorations in the anterior maxilla: anatomic and surgical considerations. *Int J Oral Maxillofac Implants* 2004; **19** (Suppl): 43–61.
65. Buser D, Belser UC, Wismeijer D, eds. *ITI treatment guide*, Vol. I: *Implant therapy in the esthetic zone for single-tooth replacements.* Berlin: Quintessence, 2007.
66. Araújo MG, Sukekava F, Wennström JL, Lindhe J. Ridge alterations following implant placement in fresh extraction sockets: an experimental study in the dog. *J Clin Periodontol* 2005; **32**: 645–52.
67. Lorenzoni M, Pertl C, Wimmer G, Wegscheider WA. Immediate loading of single-tooth implants in the anterior maxilla. Preliminary results after one year. *Clin Oral Implants Res* 2003; **14**: 180–7.
68. Hui E, Chow J, Li D, Liu J, Wat P, Law H. Immediate provisional for single-tooth implant replacement with Brånemark system: preliminary report. *Clin Implant Dent Relat Res* 2001; **3**: 79–86.
69. Wöhrle PS. Single-tooth replacement in the aesthetic zone with immediate provisionalization: fourteen consecutive case reports. *Pract Periodontics Aesthet Dent* 1998; **10**: 1107–14.
70. Kan JYK, Rungcharassaeng K, Sclar A, Lozada JL. Effects of the facial osseous defect morphology on gingival dynamics after immediate tooth replacement and guided bone regeneration: 1-year results. *J Oral Maxillofac Surg* 2007; **65** (7 Suppl 1): 13–19.
71. Ganeles J, Rosenberg MM, Holt RL, Reichman LH. Immediate loading of implants with fixed restorations in the completely edentulous mandible: report of 27 patients from a private practice. *Int J Oral Maxillofac Implants* 2001; **16**: 418–26.
72. Koutouzis T, Wennstrom JL. Bone level changes at axial- and non-axial-positioned implants supporting fixed partial dentures: a 5-year retrospective longitudinal study. *Clin Oral Implants Res* 2007; **18**: 585–90.
73. Taylor TD, Agar JR, Vogiatzi T. Implant prosthodontics: current perspective and future directions. *Int J Oral Maxillofac Implants* 2000; **15**: 66–75.
74. Amsterdam M, Abrams L. Periodontal prosthesis. In: Goldman HM, Cohen DW, eds. Periodontal therapy. St Louis, MO: Mosby, 1973.
75. Jung R, Schneider D, Ganeles J, Wismeijer D, Hämmerle F, Tahmaseb A. Computer technology applications in surgical implant dentistry: a systematic review. *Int J Oral Maxillofac Implants* 2009; **24** (suppl): 92–109.
76. Komiyama A, Klinge B, Hultin M. Treatment outcomes of immediately loaded implants installed in edentulous jaws following computer-assisted virtual treatment planning and flapless surgery. *Clin Oral Implants Res* 2008; **19**: 677–85.
77. Oyama K, Kan JYK, Kleinman AS, Runcharassaeng K, Lozada JL, Goodacre CJ. Misfit of implant fixed complete denture following computer-guided surgery. *Int J Oral Maxillofac Implants* 2009; **24**: 124–30.
78. van Steenberghe D, Glauser R, Blomback U, Andersson M, Schutyser F, Pettersson A, Wendelhag I. A computed tomographic scan-derived customized surgical template and fixed prosthesis for flapless surgery and immediate loading of implants in fully edentulous maxillae: a prospective study. *Clin Implant Dent Relat Res* 2005; **7** (Suppl 1): 111–20.
79. Casap N, Wexler A, Persky N, Schneider A, Lustmann J. Navigational surgery for dental implants: assessment of accuracy of the image-guided implantology system. *J Oral Maxillofac Surg* 2004; **62** (Suppl 2): 116–19.
80. Casap N, Wexler A, Tarazi E. Application of a surgical navigation system for implant surgery in a deficient alveolar ridge postexcision of an odontogenic myxoma. *J Oral Maxillofac Surg* 2005; **63**: 982–8.
81. Dawson A, Chen S, eds. *The SAC classification in implant dentistry*. Berlin: Quintessence, 2009.

Chapter 21

Prosthodontic treatment of the malpositioned implant and implant occlusal complications

Thomas D. Taylor DDS, MSD, FACP

Introduction

Complications that result from implant malposition or occlusal factors are some of the more common complications seen in implant dentistry. These two factors, malposition and occlusion, are frequently cofactors as etiologic agents in the failure or compromise of implant-supported/retained restorations and, as such, will be discussed in tandem.

Scope and frequency of problems

Complications related to implant malposition or to occlusal factors are, perhaps, the most common type of implant complication seen. Ceramic fracture, occlusal screw loosening or fracture, abutment or abutment screw loosening or fracture, and even implant fracture, are all possible sequelae of compromised implant position or occlusal loading. Goodacre (1) states that prosthodontic complications occur in a substantially high percentage of patients treated and are dependent on the specific type of treatment and prosthesis involved. Rates of prosthetic complications ranged from 30% for overdenture clip or attachment loosening to 10% for esthetic complications of implant-borne prostheses. These range from the minor inconvenience-type complications of occlusal screw loosening to the catastrophic complication of implant fracture. Virtually all of these prosthetic complications can be related to mechanical loading problems associated with unfavorable loading magnitude or direction and fatigue failure associated with cyclic loading over extended periods. Almost all complications associated with esthetic compromise or manifesting as loosening or fracture of implant-supported or retained components may be linked to implant positional or loading factors (2).

Fig. 21.1 Laboratory cast showing implant-supported crowns before delivery. The excessive buccal inclination of the implants and the resulting lingual cantilever of the restorations make future complication likely. Occlusal or abutment screw loosening or fracture are likely short-term complications, while implant fracture may be a long-term result of undesirable implant placement.

Etiology

Why were they put there in the first place?

Implant placement and position have in many cases been at the discretion of the surgeon. Less than ideal implant position has frequently been explained as being necessary owing to lack of available bone for implant placement or the patient's unwillingness to undergo augmentation procedures to replace or restore inadequate osseous contour or volume. Surgeon-driven implant placement and position has been largely due to the lack of planning and/or responsibility for planning on the part of the restoring dentist. Inadequate diagnosis and treatment planning on the part of the restoring dentist and the absence of restorative input at the treatment planning stage are common causes of less than desirable outcomes for dental implant therapy (Figs 21.1, 21.2).

Positional complications may result in esthetic complications or mechanical complications (Figs 21.3–21.7). An esthetic complication can be defined as any outcome that is less than ideal as it relates to the esthetic image of the restoration. There is a wide range of esthetic complications, from a subtle discrepancy in soft-tissue height or papilla contour to gross deviations from normal anatomy (Figs 21.8, 21.9). Many complications arising from implant malposition are dealt with by the use of angled or custom abutments or restorative components that compensate for positional complications. Although such modifica-

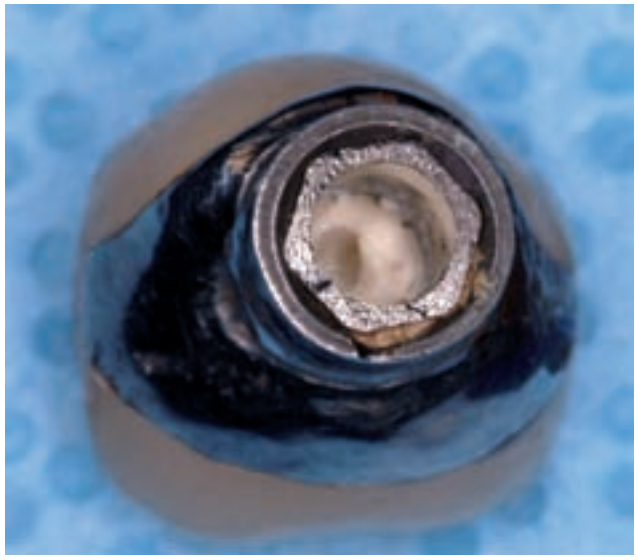


Fig. 21.2 A clinical situation in which the supporting abutment for a cement-retained, implant-supported crown has fractured. The cause of failure may be the result of the relatively small diameter of the abutment compared to the large dimensions of the restoration.

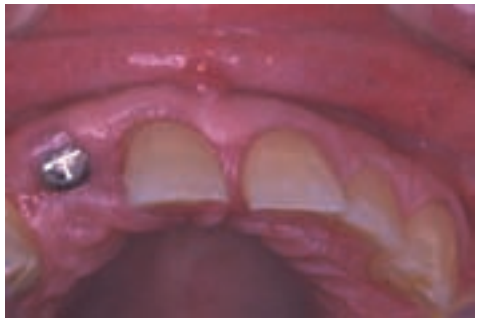


Fig. 21.3 Implant placement has resulted in a situation that can only be corrected by first removing the implant, reconstructing the bony site and placement of a new implant. This type of complication could easily have been avoided with improved communication between the surgeon and restorative dentist. Site augmentation/preparation and the use of a surgical guide for implant placement are two approaches that were not followed in this case.

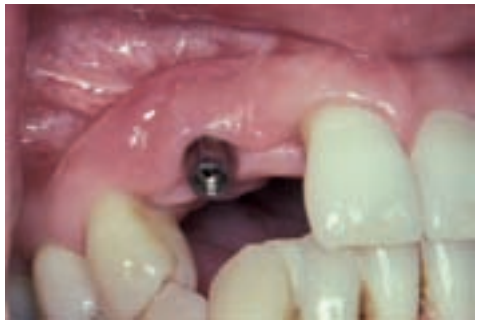


Fig. 21.4 Implant position complication caused by placement of a single implant in the embrasure space between the positions of two adjacent missing teeth. The implant is also placed far facially, making an esthetic restoration virtually impossible to accomplish. The restorative dentist had requested a single implant to be placed in the canine position but failed to provide the surgeon with a surgical guide.

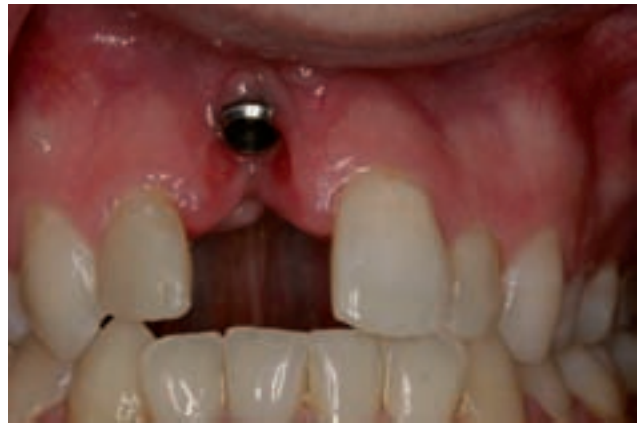


Fig. 21.5 Implant placement directed too far to the facial. The implant was subsequently removed and the site was surgically reconstructed for a future implant placement.

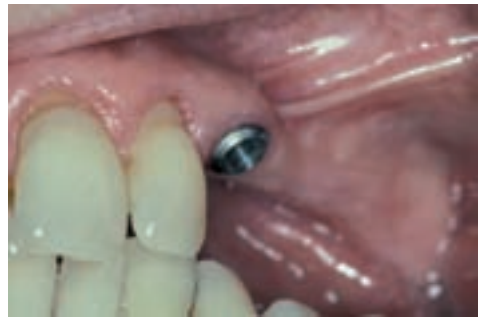


Fig. 21.6 Single implant placed into the canine position to support a crown and to serve as an abutment for a removable partial denture. The implant was placed into available bone necessitating severe labial inclination. Preimplant surgical site preparation would have led to improved implant position/angulation.

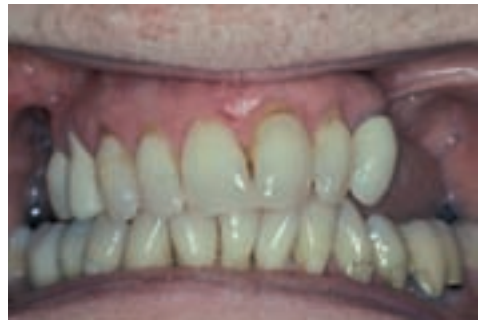


Fig. 21.7 Final metal–ceramic restoration of the implant in Fig. 21.6. The restoration is compromised esthetically owing to the need to excessively contour the facial aspect of the restoration and the resulting thin, bright ceramic of the facial surface necessitated by the need to keep the thickness to a minimum.

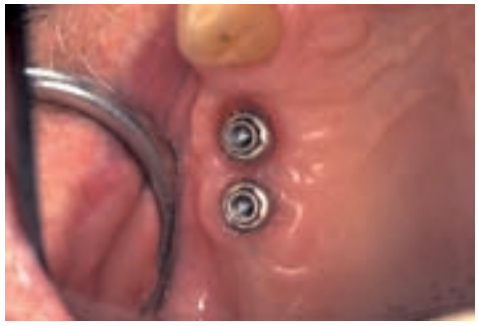


Fig. 21.8 Two implants placed in the positions of the maxillary right first and second premolars. Implant position appears adequate; however, the distance between the first premolar implant and the canine became an esthetic compromise owing to the inability to camouflage the position of the implant relative to normal tooth embrasure contours.

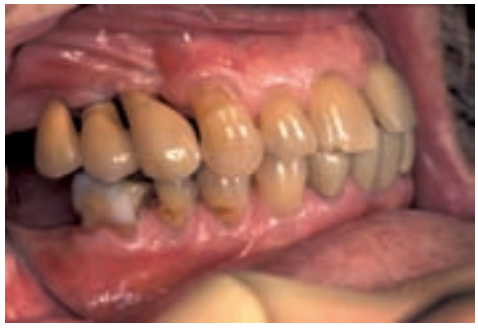


Fig. 21.9 Final metal–ceramic prosthesis placed on implants in Fig. 21.8. The esthetic result is compromised owing to the resorbed residual ridge anatomy and the placement of the anterior implant in the position of the embrasure between the normal position of the two premolar teeth.

tions may solve the esthetic problem they usually increase the level of complexity and cost of treatment and may result in mechanically weaker final restorations.

Mechanical complications associated with implant malposition are most frequently associated with unfavorable cantilever load distribution that places the implant-supported restoration under substantial bending load (moment) and increases the risk of structural failure (Fig. 21.10). The question of whether non-axial loading is detrimental to the long-term success of osseointegrated dental implants is a frequently discussed issue. On the one hand, it would make sense that non-axial loading of an implant could create areas of focussed compressive (or shear) loading that are considered detrimental to bone and the osseointegrated interface. On the other hand, when one considers that many implants are intentionally placed in a non-axial relationship to the occlusal table and yet function successfully over the long term (e.g. zygomatic implants, implants supporting fixed terminal cantilever prostheses with ≥20 mm of length in the edentulous mandible, maxillary anterior implants which must be placed 135 degrees or more off-axis to the occlusal plane), it must be realized that perhaps non-axial loading is not as detrimental to the osseointegrated

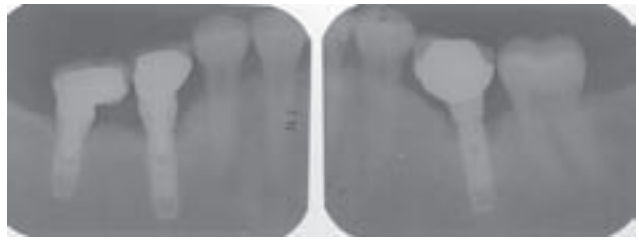


Fig. 21.10 Radiographic images of posterior mandibular implants replacing molar teeth. Bone loss associated with the implants in positions 19 and 30 was determined to be associated with implants that were partially fractured at the level of the abutment screw. Fracture was likely due to fatigue caused by bending moments generated by the wide occlusal platform of the implant-supported restorations.

interface as has been suggested. When one also realizes that human occlusion is rarely vertical in nature it would be impossible to create a situation where occlusal loading could be purely axial in nature.

There is very little scientific evidence concerning the issue of axial versus non-axial loading. Two papers have specifically looked at this issue in animal studies and both studies concluded that non-axial loading was not detrimental to the osseointegration interface or to attachment levels adjacent to implants (3, 4). While there is currently no evidence that non-axial loading is detrimental to the interface of osseointegration, it is obvious to any experienced clinician that non-axial loading can be extremely damaging to the mechanical components of an implant-supported restoration (including the body of the implant). Such non-axial loads are considered to be the cause of component fracture and screw loosening in many clinical situations.

Prevention

Treatment planning and presurgical preparation

The best way to avoid compromised treatment outcomes is to maximize pretreatment diagnosis and treatment planning. Thorough clinical and radiologic examination, the fabrication of accurate mounted diagnostic casts, and in-depth discussion with the patient regarding treatment options, expectations, and possible outcomes, are necessary to minimize complications after treatment. In most practices, treatment planning is a team approach between surgical and restorative dentist. While the surgeon is responsible for implant placement the restorative dentist is responsible for instructing the surgeon as to the preferred location and distribution of implant placement. It is not appropriate for the restorative dentist to relinquish this aspect of treatment to the surgeon and then complain about the outcome of placement after the fact. If ideal implant position cannot be created because of

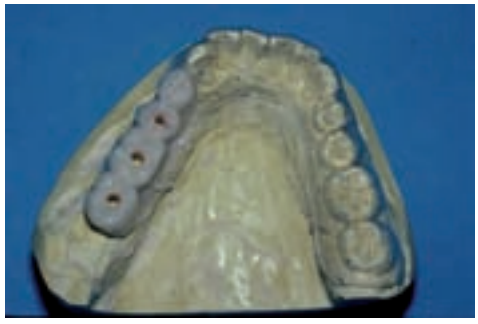


Fig. 21.11 Typical surgical guide fabricated from a vacuum-formed thermoplastic sheet. Surgical guides need not be complicated or expensive to fabricate. They should also be designed with the surgical situation in mind to facilitate use at the time of implant placement.

anatomic deficiencies it becomes the task of the surgeon to propose soft- and/or hard-tissue augmentation procedures to make ideal implant position an attainable goal. The restoration of natural osseous and soft-tissue contours will allow more ideal implant placement and will improve the chances of a satisfactory outcome to therapy.

The fabrication of surgical guides for implant placement is a procedure that should be routine in every restorative practice involved with dental implant therapy. Surgical guides do not usually need to be complex or expensive to function successfully. A surgical guide must provide an accurate replication of desired implant position, must be usable with soft-tissue flaps reflected, and must allow for easy use by the surgeon. Surgical guides are most frequently fabricated with vacuum-formed thermoplastic templates placed over a diagnostic cast with the position of the final restoration on it (Fig. 21.11). The holes or slots created to allow drill insertion must be convenient and of sufficient size to allow at least two sequential drill sizes to be used with the guide in place. Commercially available drilling sleeves of various sizes are available that can be incorporated into the surgical guide and are recommended in situations where even small deviation from ideal positioning would impact treatment outcome.

Treatment

Management of mechanical problems in dealing with the malpositioned implant

In a situation where malposition has already occurred the corrective treatment may range from a simple modification of restoration design to the need to remove the implant and start again with treatment planning. Most frequently, the successful treatment of a malpositioned implant lies somewhere between these extremes. Mechanical problems associated with implant malposition usually relate to unfavorable restoration position and/or contour relative to the implant pillar. Severe malposition can substantially increase the potential for catastrophic failure of the components of the implant pillar, including the body of the implant.

Management of esthetic problems in dealing with the malpositioned implant

Esthetic complications that are the result of improper implant position usually reflect the fact that the site for implant placement is already compromised before the implant is placed. Insufficient hard- and/or soft-tissue volume and contour that preclude ideal implant placement must be corrected surgically as a preliminary step in treatment if an optimal esthetic outcome is desired. To assume that implant position errors can always be corrected by restorative procedures is hazardous at best. Surgical site preparation must be a routine part of implant planning and placement.

Etiology of occlusal complications

Does occlusion cause implant failure?

Many clinicians have seen implants fail in situations in which occlusion is the likely cause of failure. In spite of this, there is very little evidence that occlusal forces can cause loss of osseointegration. The currently available evidence (virtually all from animal studies) demonstrates that osseointegrated dental implants are extremely resistant to excessive occlusal load and overload (3–9).

Of the studies reviewed here, only Isidor (7) was able to demonstrate any negative effect on implant-to-bone contact by occlusal forces. The remaining studies were not able to demonstrate a cause and effect relationship between occlusal forces and loss of osseointegration. It can be argued that the design of the Isidor study placed such an extreme loading environment on the implants in the second stage of the study as to be of little clinical relevance, particularly when one considers the results of other similar animal studies. Overall, current evidence does not point to occlusal forces as being a substantial risk factor for loss of osseointegration. However, excessive and/or non-axial loading of an implant may place that implant at risk for catastrophic mechanical failure due to overload or flexure fatigue (Fig. 21.12).

While the effect of occlusion on the stability of healed implants with a mature interface of osseointegration has been clearly demonstrated in multiple animal studies, caution must be exercised when dealing with immediately loaded dental implants. Some clinicians advocate aggressive immediate loading of dental implants, while others caution that immediate loading puts the implant at increased risk of failure to integrate. Evidence is clear

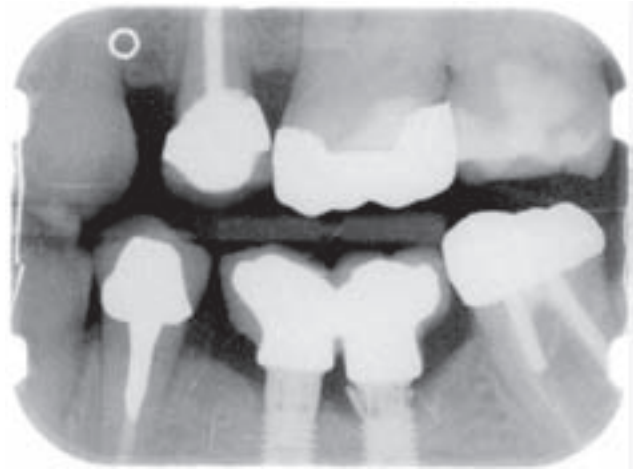


Fig. 21.12 Radiographic image of a fractured internal connection implant. The implant fractured through internal hoop stresses generated by occlusal loading of the implant-supported crown. The presence of a splinted second implant and sound adjacent teeth did not prevent this catastrophic failure. It is likely that internal connection implants will be shown to be susceptible to hoop stress failure as the time from loading increases. Fatigue failure of metals is time dependent.

that the sequence of wound healing and the creation of the osseointegrated interface is susceptible to failure when initial primary stability of the implant is inadequate to withstand occlusal loading without causing motion between the implant and surrounding bone. Even when initial primary stability is adequate to resist loading, as primary stability is replaced by secondary stability (bone remodeling leading to osseointegration) there is likely to be a period of reduced overall stability of the healing osseointegration interface which could put the implant at increased risk for failure due to occlusal loading (10).

Parafunction, particularly bruxism, has been cited as a contraindication to dental implant therapy. However, when one considers the alternatives to the use of dental implants to replace teeth in bruxing patients it is clear that all methods of tooth replacement are at greatly increased risk of failure when placed into the mouth of the bruxer. So, rather than stating that dental implants are contraindicated in the bruxer, it should be stated that all reconstructive dentistry is contraindicated for the bruxer. True bruxism is a complex disease of (probably) multifactorial origin that has no cure and for which treatment has been shown to be ineffective. If the patient can be educated to this fact and the responsibility for the failure of dentistry in the bruxer's mouth can clearly be placed on the shoulders of the patient, the use of dental implants to replace missing teeth should not be contraindicated any more than any other form of restorative or reconstructive dentistry for that patient. Said another way, if the patient understands that his or her increased risk of oral destruction is not something that the dentist can control, the use of dental implants should be considered the treatment of choice for such patients.

Why does the porcelain keep breaking?

In spite of the apparent lack of evidence relating to a cause and effect relationship between occlusal forces and loss of osseointegration, it is very reasonable to assume that occlusal forces are extremely damaging to the mechanical components of an implant-supported restoration. The lack of periodontal ligament support for implant-borne restorations is frequently cited as a causative factor in implant restoration complications, particularly those related to component loosening or fracture. It is thought by many that the ankylotic nature of the implant-to-bone connection potentially acts to magnify the transmission of occlusal forces through the implant pillar without the cushioning or dampening effect that the periodontal ligament normally provides in the natural dentition. This lack of cushioning effect is thought to place the mechanical components of the implant pillar at increased risk of complications through component loosening or fracture.

Another potential cause of an increased incidence of complications related to occlusal forces on dental implants is the loss of proprioceptive innervation that results from loss of natural teeth. Several studies have documented the reduction in proprioceptive capability of dental implants compared to natural teeth (11–15). The reduction in discriminatory capability after natural tooth loss is real. The clinical importance of this reduction is yet to be determined. While the loss of the proprioceptive capability of the periodontal ligament is clear, remaining proprioceptive nerve endings present in the mucosa, periosteum, masticatory muscles, and temporomandibular joint and ligaments seem, clinically, to accommodate for the loss of periodontal ligament sensory nerve endings.

A more likely cause of component failure, particularly ceramic fracture of implant-supported restorations, may be found in the design and construction of implant-supported restorations (Fig. 21.13). When fabricating a crown

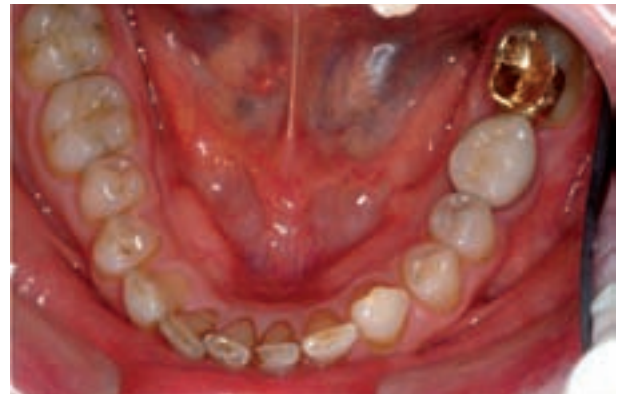


Fig. 21.13 Mandibular first molar implant crown placed shortly before the distolingual cusp fractured through cohesive porcelain failure. In this case failure was likely due to inadequate core support for the veneering porcelain, leaving it unsupported and susceptible to fracture.

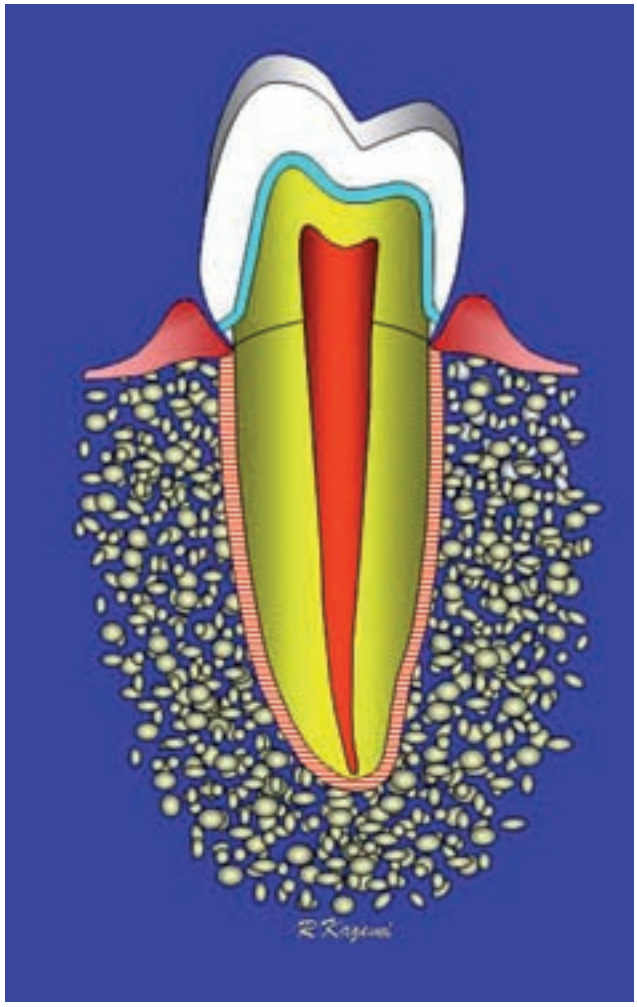


Fig. 21.14 When a natural tooth is prepared for a crown the reduction in tooth structure is generally somewhat uniform, allowing for a relatively even thickness of restorative material, which adds strength to the structure and minimizes the risk of unsupported porcelain.

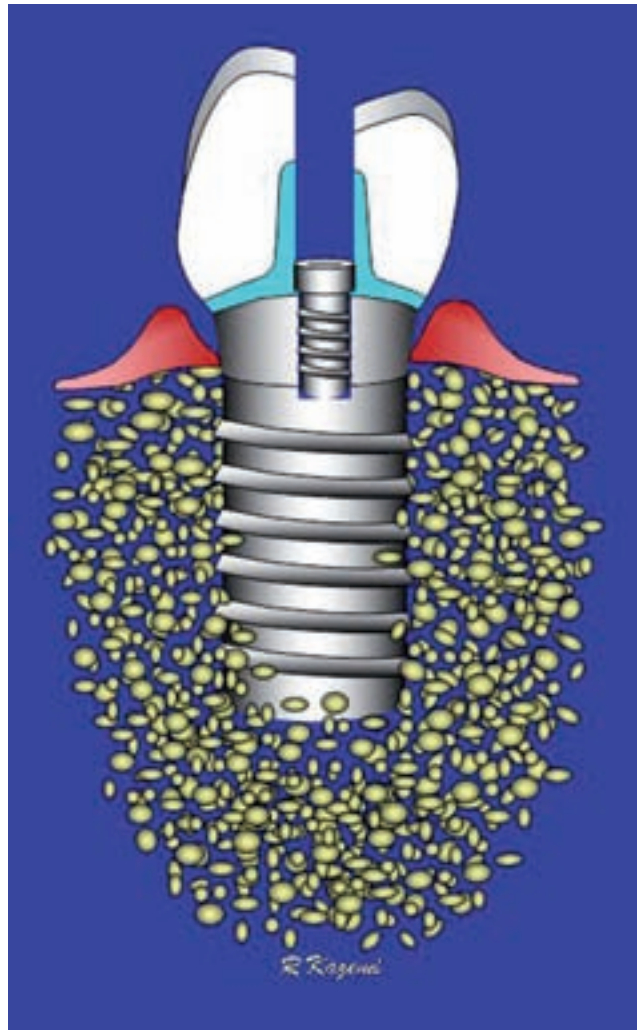


Fig. 21.15 Unlike a natural tooth preparation, a screw-retained, implant-supported crown is frequently fabricated from a premanufactured plastic or cast-to-metal coping. The discrepancy between the size and shape of the coping is compensated for by the addition of excessive veneering porcelain to create normal tooth contours.

in a natural tooth situation, the tooth is prepared for a crown by relatively uniform reduction of normal tooth contours to create space for the restoration (Fig. 21.14). When an implant-supported restoration is fabricated it is frequently created from a prefabricated coping provided by the implant manufacturer. The coping lacks normal tooth preparation contours and the final restoration may result in the build-up of excess veneering porcelain (Figs 21.15, 21.16). The resulting unsupported porcelain is more susceptible to fracture (Fig. 21.17).

Prevention of occlusal complications

Prevention of occlusion-related ceramic fracture

A solution to this potential problem is to create a coping that more closely reflects the final contour and volume of the anticipated final restoration. This can be done by customizing the stock prefabricated coping by waxing to full contour and then cutting back to make room for the veneering porcelain (Fig. 21.18). Another solution would be to use a custom abutment that more closely reflects the shape of the final restoration (Fig. 21.19).

The risk of ceramic failure of implant-supported restorations can be substantially reduced by following sound dental laboratory principles to avoid restorations with large amounts of unsupported porcelain.

The issue of whether to splint multiple adjacent implants together or to leave them as individual units is a frequent topic of discussion. There is no current scientific evidence that one is preferable to the other when considering post-treatment complications and/or failures. So, in the face of no evidence the clinician must make the determination based on personal experience and the empirical advice of others. Complications such

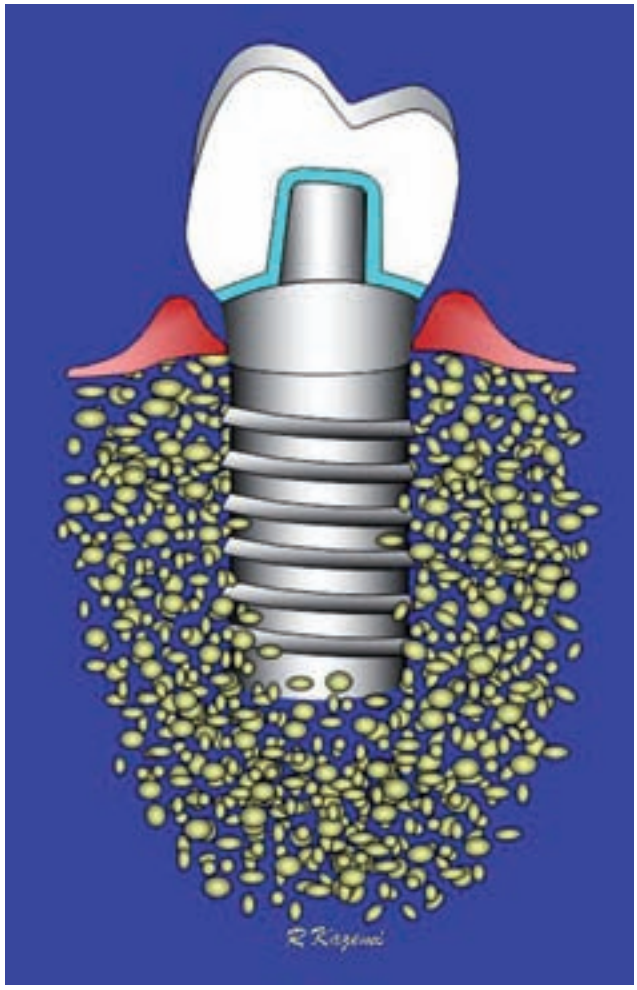


Fig. 21.16 Similar to Fig. 21.15, a cemented implant crown, although lacking a screw access hole, is also fabricated with a premanufactured plastic or metal coping, leading once again to potentially unsupported veneering porcelain in the final restoration.

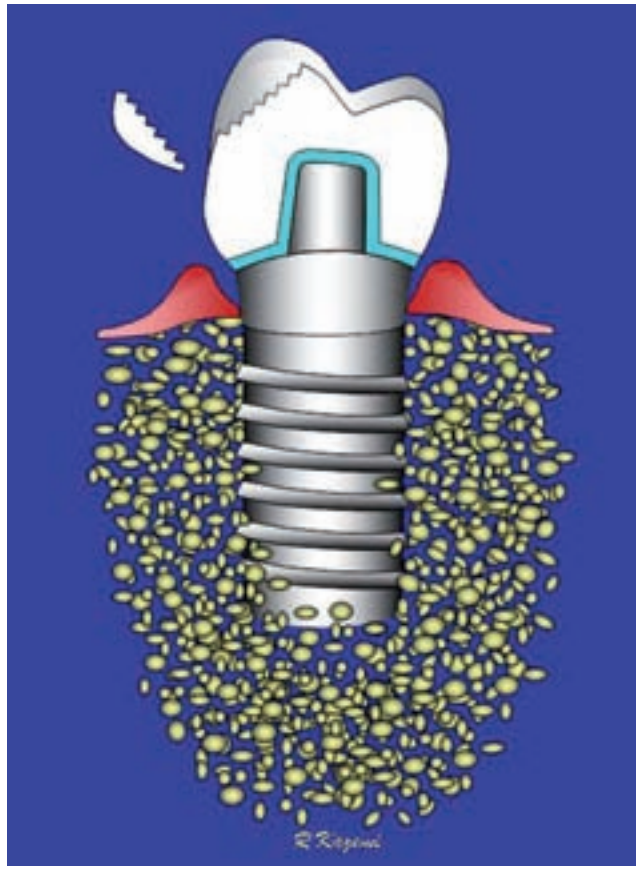


Fig. 21.17 Under normal oral function unsupported veneering porcelain is more susceptible to fracture than in a situation where the porcelain is of more ideal thickness and is well supported by its core.

as screw loosening and restorative material fracture may in any given clinical situation be the result of inadequate stability of the implant pillar or splinted assembly due to patient-related factors, implant component or design factors, or laboratory technology factors. It is not possible to make scientifically based recommendations on this issue. There are clinical advantages to both methods. A primary advantage of keeping individual units separate is that if a complication occurs it is limited to a single implant pillar complex rather than to a multiple unit restoration and is therefore easier to rectify. A major advantage of splinting multiple units together is the avoidance of adjusting multiple interproximal contacts between units, which is an extremely difficult and time-consuming procedure when done properly. Contact point adjustment between natural teeth is easier than it is between two adjacent implants because of the presence of the periodontal ligament, which will allow slight tooth movement to allow the floss to pass through the contact. With two adjacent implants there is no compensatory periodontal ligament mobility and the proximal contact must be adjusted to be slightly open to allow floss passage. The presence of this slightly open contact may be inconsequential or may increase the risk of food impaction between restorations. It may also cause an esthetic compromise in the anterior part of the mouth.

The use of combined implant and natural tooth support for multiple-unit fixed prostheses has generally been avoided by most clinicians. The differential mode of support for implants and natural teeth would seem to preclude using both simultaneously to support a fixed prosthesis. Early reports of natural tooth intrusion and migration associated with tooth–implant-supported prostheses were cited as reason enough to avoid such combinations. Alternatively, at several European centers the use of a single molar position implant and a natural premolar anterior abutment as support for three- or four-unit fixed partial dentures was common practice for many years. A recent study analyzed the outcomes of a 10-year study comparing tooth–implant-supported fixed partial dentures to implant–implant-supported fixed partial dentures (16). The authors found a statistically

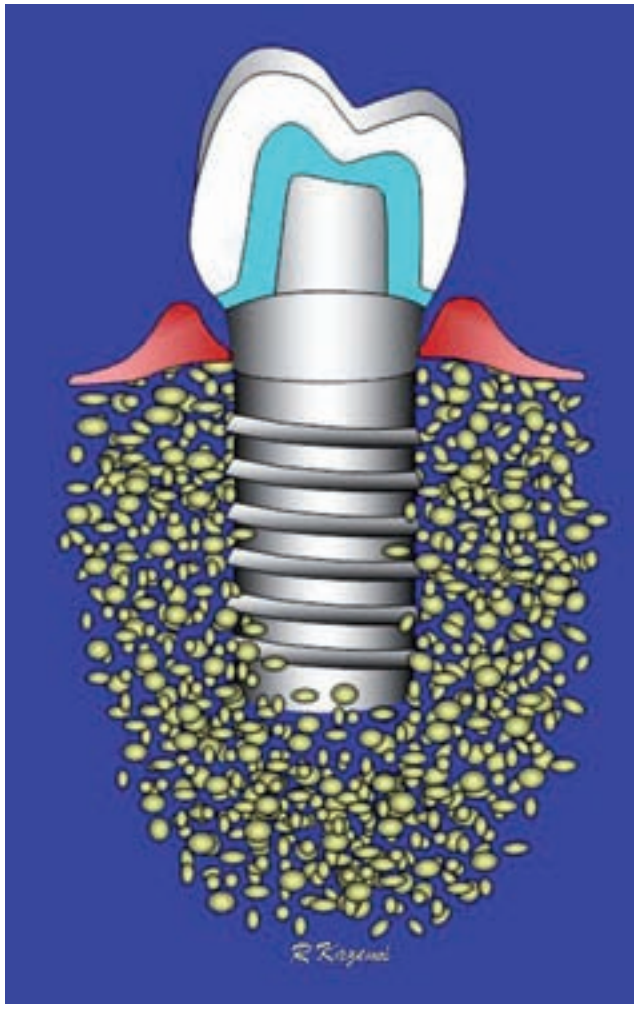


Fig. 21.18 By requesting that the laboratory technician generate a full contour wax-up of the final restoration, perform cut-back similar to what would be done with a natural tooth-based restoration, cast and veneer porcelain, the clinician can decrease the risk of excessively unsupported porcelain in the final restoration. While this will slightly increase the time and metal expended by the technician the increased strength of the final restoration will more than offset the additional laboratory fee and metal cost involved.

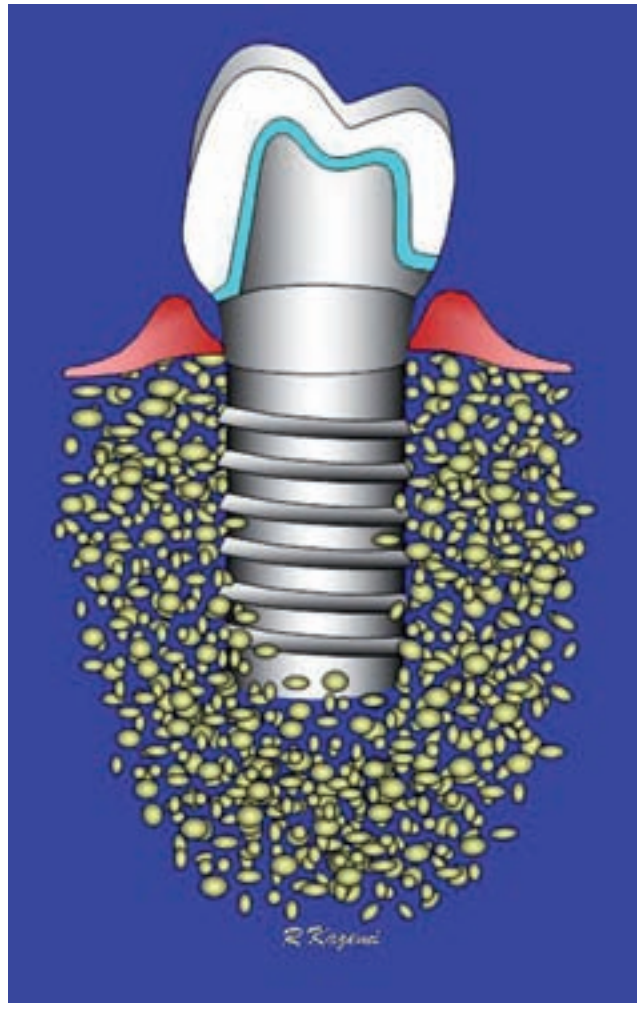


Fig. 21.19 Another option useful in avoiding the problem of unsupported porcelain is to use custom abutments that are shaped similarly to a prepared natural tooth, allowing for the final restoration to be made with more reasonable thickness of veneering porcelain.

significant increase in biologic complications of tooth–implant-supported prostheses compared to implant–implant-supported prostheses. They also found a statistically significant increase in mechanical complications with the tooth–implant combination than with the implant–implant design. From this limited scientific evidence and a broader general consensus it is advisable to avoid tooth to implant connections whenever possible.

Conclusion

Complications resulting from positional and occlusal problems can best be treated by avoiding them in the first place. Proper diagnosis and treatment planning are key to successful implant rehabilitation.

Take-home hints

- Never place an implant without having the final restoration planned. This is clearly the most important rule in dental implant treatment planning.
- Never modify the planned position of an implant at the time of surgery without considering the effect it will have on the success of the final restoration.
- A positional error, once it happens, is rarely a simple problem to correct.
- Positional error/non-axial loading of a dental implant is unlikely to affect the stability of the implant relative to the bone but is very likely to cause mechanical problems with the implant pillar and/or restoration.

Bruxism is not a contraindication for implant dentistry: it is a complication for any dentistry. But in lieu of a better solution, dental implants are the best option for replacing missing teeth in the bruxing patient. The critical point here is that bruxism is a severely debilitating disease of unknown etiology which has no cure. As long as the patient understands that the problem is theirs and not the care provider's, implant therapy should be the treatment of choice for replacement of missing teeth in the bruxing patient.

Acknowledgment

Figures 21.14–21.19 are provided courtesy of Dr Reza B. Kazemi; reprinted with permission.

References

1. Goodacre C, Bernal G, Rungcharassaeng K, Kan J. Clinical complications with implants and implant prostheses. *J Prosthet Dent* 2003; **90**: 121–32.
2. Rangert B, Krogh P, Langer B, Van Roekel N. Bending overload and implant fracture: a retrospective clinical analysis. *Int J Oral Maxillofac Implants* 1995; **10**: 326–34.
3. Asikainen P, Klemetti E, Vuillemin T, Sutter F, Rainio V, Kotilainen R. Titanium implants and lateral forces. *Clin Oral Implants Res* 1997; **8**: 465–86.
4. Celleti R, Pameijer C, Bracchetti G, Donath K, Persichetti G, Visani I. Histologic evaluation of osseointegrated implants restored in nonaxial functional occlusion with preangled abutments. *Int J Periodontics Restorative Dent* 1995; **15**: 563–73.
5. Heitz-Mayfield L, Schmid B, Weigel C, Gerber S, Bosshardt D, Jonsson J, Lang N. Does excessive occlusal load affect osseointegration? An experimental study in the dog. *Clin Oral Impants Res* 2004; **15**: 259–68.
6. Hurzeler M, Quinones C, Kohal R, Rohde M, Strub J, Teuscher U, Caffesse R. Changes in peri-implant tissues subjected to orthodontic forces and ligature breakdown in monkeys. *J Periodontol* 1998; **69**: 396–404.
7. Isidor F. Loss of osseointegration caused by occlusal load of oral implants. A clinical and radiographic study in monkeys. *Clin Oral Implants Res* 1996; **7**: 143–52.
8. Miyata T, Kobayashi Y, Araki H, Motomura Y, Shin K. The influence of controlled occlusal overload on peri-implant tissue: a histologic study in monkeys. *Int J Oral Maxillofac Implants* 1998; **13**: 677–83.
9. Ogiso M, Tabata T, Kuo P, Borgese D. A histologic comparison of the functional loading capacity of an occluded dense apatite implant and the natural dentition. *J Prosthet Dent* 1994; **71**: 581–8.
10. Raghavendra S, Wood M, Taylor T. Early wound healing around endosseous implants: a review of the literature. *Int J Oral Maxillofac Implants* 2005; **20**: 425–31.
11. El-Sheikh A, Hobkirk J, Howell P, Gilthorpe M. Passive tactile sensibility in edentulous subjects treated with dental implants: a pilot study. *J Prosthet Dent* 2004; **91**: 26–32.
12. Hämmerle C, Wagner D, Brägger U, Lussi A, Karayiannis A, Joss A, Lang N. Threshold of tactile sensitivity perceived with dental endosseous implants and natural teeth. *Clin Oral Implants Res* 1995; **6**: 83–90.
13. Jacobs R, van Steenberghe D. Comparison between implant-supported prostheses and teeth regarding passive threshold level. *Int J Oral Maxillofac Implants* 1993; **8**: 549–54.
14. Mericske-Stern R, Hofmann J, Wedig A, Geering A. *In vivo* measurements of maximal occlusal force and minimal pressure threshold on overdentures supported by implants or natural roots: a comparative study, Part 1. *Int J Oral Maxillofac Implants* 1993; **8**: 641–9.
15. Mericske-Stern R, Assal P, Mericske E, Ing W. Occlusal force and oral tactile sensibility measured in partially edentulous patients with ITI implants. *Int J Oral Maxillofac Implants* 1995; **10**: 345–54.
16. Brägger U, Karoussis I, Persson R, Pjetursson B, Salvi G, Lang N. Technical and biologic complications/failures with single crowns and fixed partial dentures on implants: a 10-year prospective cohort study. *Clin Oral Implants Res* 2005; **16**: 326–34.

Chapter 22

A potpourri of surgical complications associated with dental implant placement: 35 case reports – common problems, avoidance, and management

Gary Greenstein DDS, MS *and John S. Cavallaro Jr.* DDS

Introduction

Therapists placing dental implants may be confronted with a variety of clinical issues. Avoiding and managing complications associated with implant dentistry impact on clinical efficiency. In this regard, the authors have assembled 35 situations for discussion that they, their colleagues or students have experienced. Some of the events that transpired were unexpected. Therefore, a retrospective assessment of biologic factors that contributed to these occurrences and how they could be circumvented or handled would be enlightening to clinicians who use implant treatment in their practices. This chapter will present succinct case reports that address specific clinical situations.

Problematic issues will be presented with respect to a general category that encompasses similar situations. When a case report could apply in more than one category listed below, it is discussed in the segment that seemed best suited to illustrate the issue. The case reports are presented as follows:

- Diagnosis and treatment planning: cases 1–12.
- Involved tissues:
  - soft tissue: cases 13–16
  - bone: cases 17 and 18
  - nerves: cases 19 and 20.
- Implant placement: cases 21–27.
- Postoperative problems: cases 28–30.
- Sinus issues: cases 31–34.
- Fracture of the mandible: case 35.

Diagnosis and treatment planning

Case 1: Alveolar nerve damage during implant osteotomy

Etiology

The patient in Fig. 22.1 had a high mylohyoid muscle insertion making it difficult to take a good periapical

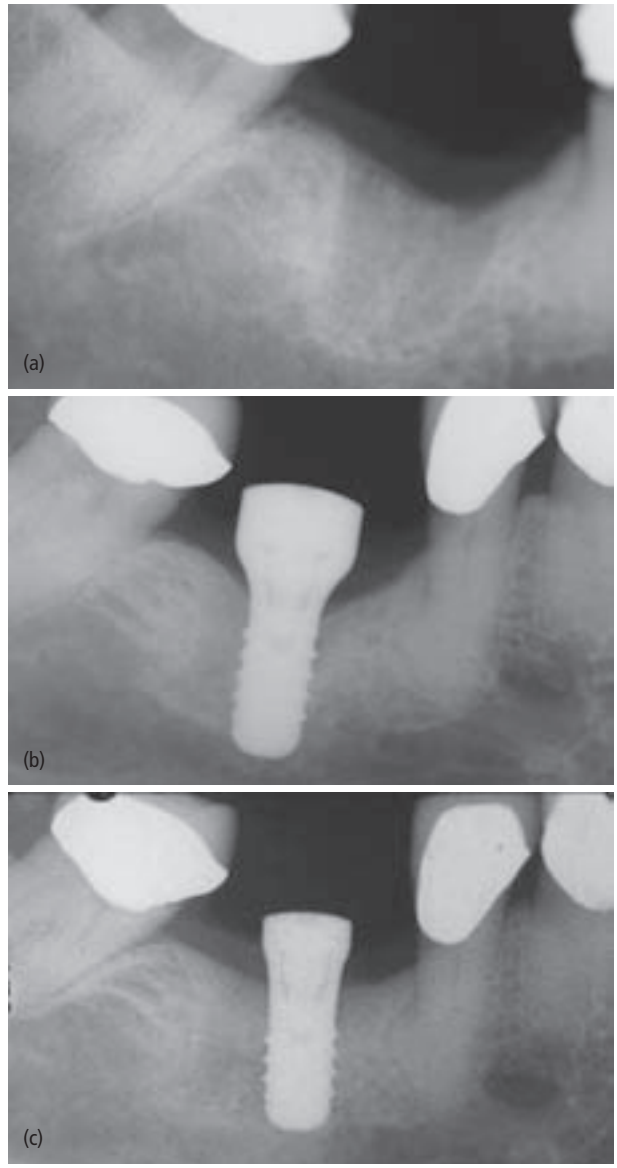


Fig. 22.1 Inferior alveolar nerve at apex of the extraction site. (a) Initial periapical radiograph of extraction site (tooth 30). (b) Implant in inferior alveolar canal (Panorex, site 30 is enlarged). (c) Implant placed at site 30 coronal to the inferior alveolar canal.

film. Figure 22.1(a) reveals radiolucent bone at the apex of the molar extraction socket. Since it was assumed that the canal would be at least 3 mm away from the apex of the tooth, this radiolucency was interpreted as the beginning of the submandibular fossa. Therefore, the treatment plan was to place a 10 mm implant that would only extend to the end of the healed root alveolus. However, when a 10 mm osteotomy was created and a 10 mm implant placed, it entered the mandibular canal. A Panorex (pertinent section of the film has been enlarged) indicated that the radiolucency seen in the periapical film was the inferior alveolar canal (Fig. 22.1b). Failure to identify the mandibular canal clearly before initiating the osteotomy resulted in not leaving a proper safety distance (2 mm) between the depth of drilling and the mandibular canal.

Prevention

In most cases, the inferior alveolar canal is located 3.5–5.4 mm apical to the apex of the mandibular first molar (1). However, there are exceptions to this statement and the canal can abut the apex of the mandibular first molar (Fig. 22.1a). Therefore, accurate diagnostic films must be obtained before implant placement. In this regard, Denio *et al.* (2) noted that in 28% of patients the mandibular canal could not be clearly recognized in the second premolar and first molar regions when using periapical radiographs. As a general precaution, if the inferior alveolar canal does not appear on a periapical film, a panoramic film should be taken. If the canal is still not clearly discernible, it is advisable to obtain a computed tomographic (CT) scan. Information can be gleaned from a panoramic film with respect to the contralateral side; however, the two sides are not always identical and there is a magnification distortion associated with panoramic radiographs. Therefore, a CT scan is recommended whenever an implant is planned in very close proximity to the inferior alveolar canal (see Chapter 24).

When creating an osteotomy coronal to the inferior alveolar canal, it should be emphasized that the mean distances between apex of a molar and the mandibular canal reported in studies may not pertain to a particular patient. Furthermore, to avoid untoward sequelae in the posterior mandible, the position of the nerve must be definitively confirmed before an osteotomy is created. In addition, it has been reported that a periapical radiograph on average has a linear error of 1.9 mm (14%) and this inaccuracy can range from 0 to 5 mm. A panoramic film has a linear error of 3.0 mm (23%) and this error can vary from 0.5 to 7.5 mm (3).

Treatment

The implant was removed. However, the patient had permanent paresthesia of the lip and gingiva. Another implant was placed 3 months later (Fig. 22.1c).

Case 2: Retention of carious compromised teeth

Etiology

This patient presented for a consultation with large carious lesions (teeth nos 12 and 13), which were asymptomatic (Fig. 22.2a).

Prevention and treatment

A treatment option included endodontic therapy, crown lengthening of the teeth, and fabrication of permanent fixed restorations. Once the need for endodontic therapy and crown lengthening was determined, it was decided to extract the teeth and proceed with implants. This decision was influenced by the fact that patients with a high caries index are susceptible to further caries (4). For these individuals, it may be wise to avoid crown lengthening and replace carious teeth with dental implants that cannot decay. This is particularly pertinent in the esthetic zone, because crown lengthening entails apical movement of soft tissue and could result in asymmetric gingival margins (Fig. 22.2b). However, it should also be noted that extractions usually result in resorption of bone and shrinkage of soft tissue; therefore, consideration should be given to socket preservation procedures at the time of extraction to avoid similar esthetic complications. Another strategy to preserve and enhance soft-tissue contour at a compromised site is to use orthodontic forced eruption of a hopeless tooth before extraction and then employ socket preservation techniques to minimize recession.

Case 3: Deterioration of future implant site due to prolonged retention of periodontally compromised teeth

Etiology

Appropriate periodontal therapy is usually successful in retaining teeth and conserving surrounding bone and soft tissue. However, there are times when retention of questionable teeth can compromise future implant sites. This situation occurred at sites 4 and 5 (Fig. 22.3a). These areas were initially treated for periodontal disease in 1998 and remained stable in 2002 and 2004 (Fig. 22.3b, c). The patient received quarterly maintenance visits and monitoring. In 2005 he had medical problems and did not appear for maintenance. In 2006, he returned and site 4 had deteriorated to the extent that after tooth extraction an implant could not be placed without prior bone augmentation using guided bone regeneration (GBR) (Fig. 22.3d).

Prevention

This case underscores the fact that if bone levels continue to worsen despite periodontal therapy, it is wise to extract compromised teeth before further osseous sup-

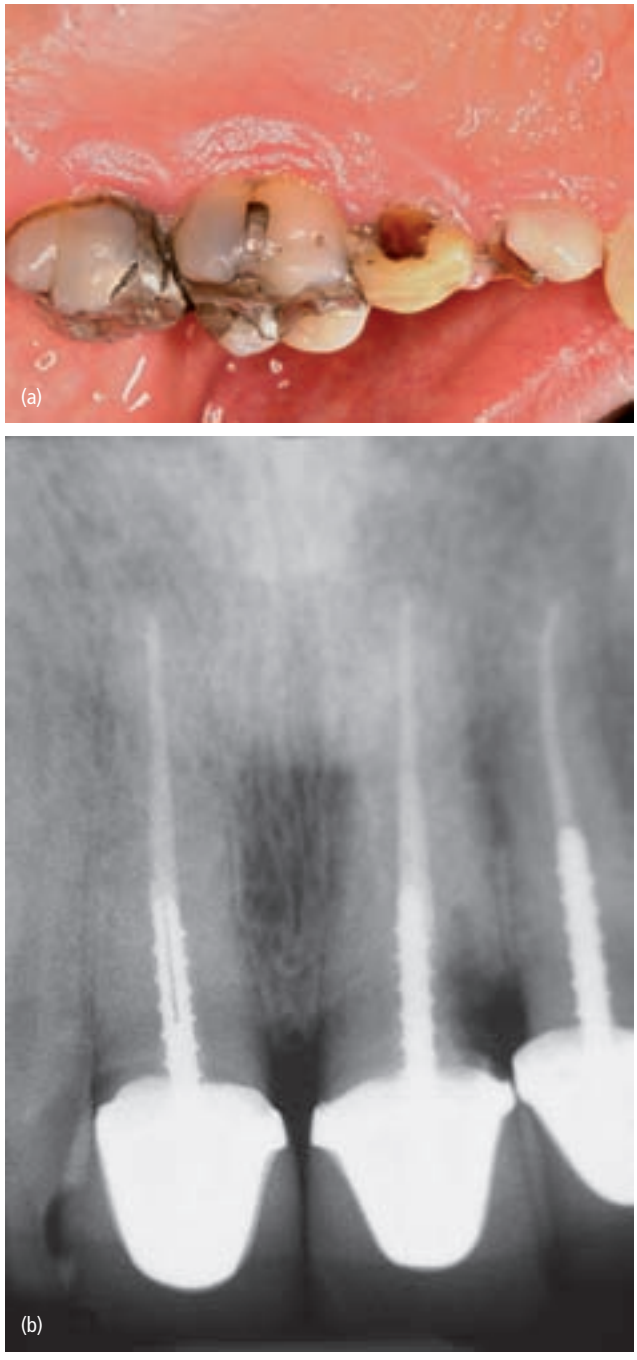


Fig. 22.2 Carious teeth: treat or extract? (a) Carious teeth in posterior region, nos 12 and 13. (b) Carious tooth in the esthetic zone, no. 9.

port is lost and the remaining bone level diminishes to less than 10 mm in height. This amount of bone is desirable when inserting an implant, since implants at least 10 mm long may exhibit better survival rates than shorter implants (5). Furthermore, in the esthetic zone, bony support is critical for maintaining good morphology of the gingival tissues. From another perspective, if it is desired to place an implant immediately after an extraction, then 4–5 mm of bone apical to the root apices is

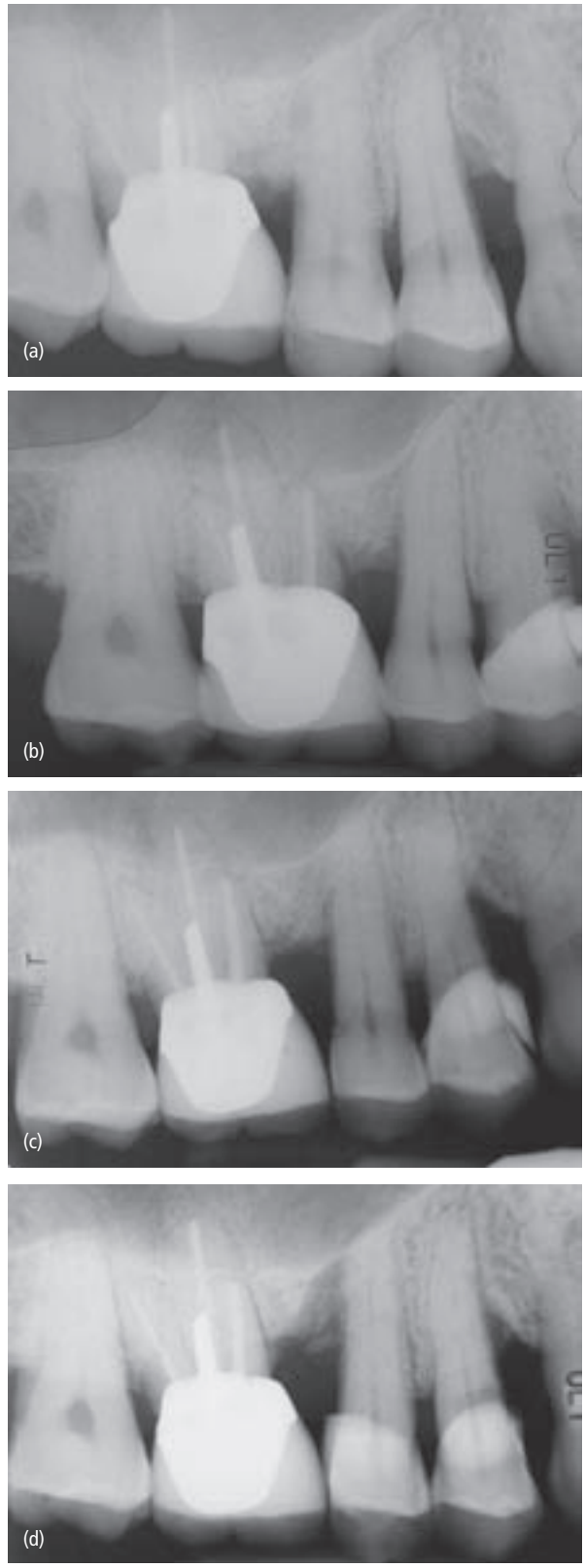


Fig. 22.3 Periodontal therapy: chronology of failure. (a) Initial radiograph (1998) of teeth 4 and 5. (b) Radiograph, 2002. The bone level is stable. (c) Radiograph, 2004. The bone level has deteriorated on the distal of tooth 4. (d) Radiograph, 2006. There is too little bone left for implants. The patient needs guided bone regeneration before implant placement at sites 4 and 5.

needed for osteotomy preparation to ensure primary implant stability and that the implant is placed in an ideal restorative position.

Treatment
At this juncture, consideration is being given to removal of teeth 4 and 5, performing a ridge augmentation, and placing two implants 6–8 months later.

Case 4: Unfulfilled surgical expectations in the esthetic zone resulting in the need to use pink porcelain

Etiology
Previous extractions of teeth 7–10 in the esthetic zone resulted in ridge resorption.

Prevention
Atraumatic (flapless) removal of compromised teeth without damaging the buccal plate of bone reduces bone resorption (6) in the esthetic zone. In addition, socket preservation procedures immediately after extraction of teeth help maintain soft-tissue contours (7, 8).

Treatment
The patient desired fixed prosthesis nos 6–11; however, a soft-tissue deficiency between teeth 7 and 10 required augmentation (Fig. 22.4a–d). Therefore, a flap was reflected and a barrier placed to retain the bone graft material (Fig. 22.4b). Primary closure was obtained by advancing the tissue. However, this resulted in loss of the buccal vestibule (Fig. 22.4c). Subsequently, there was a great deal of tissue shrinkage (Fig. 22.4d) and the final

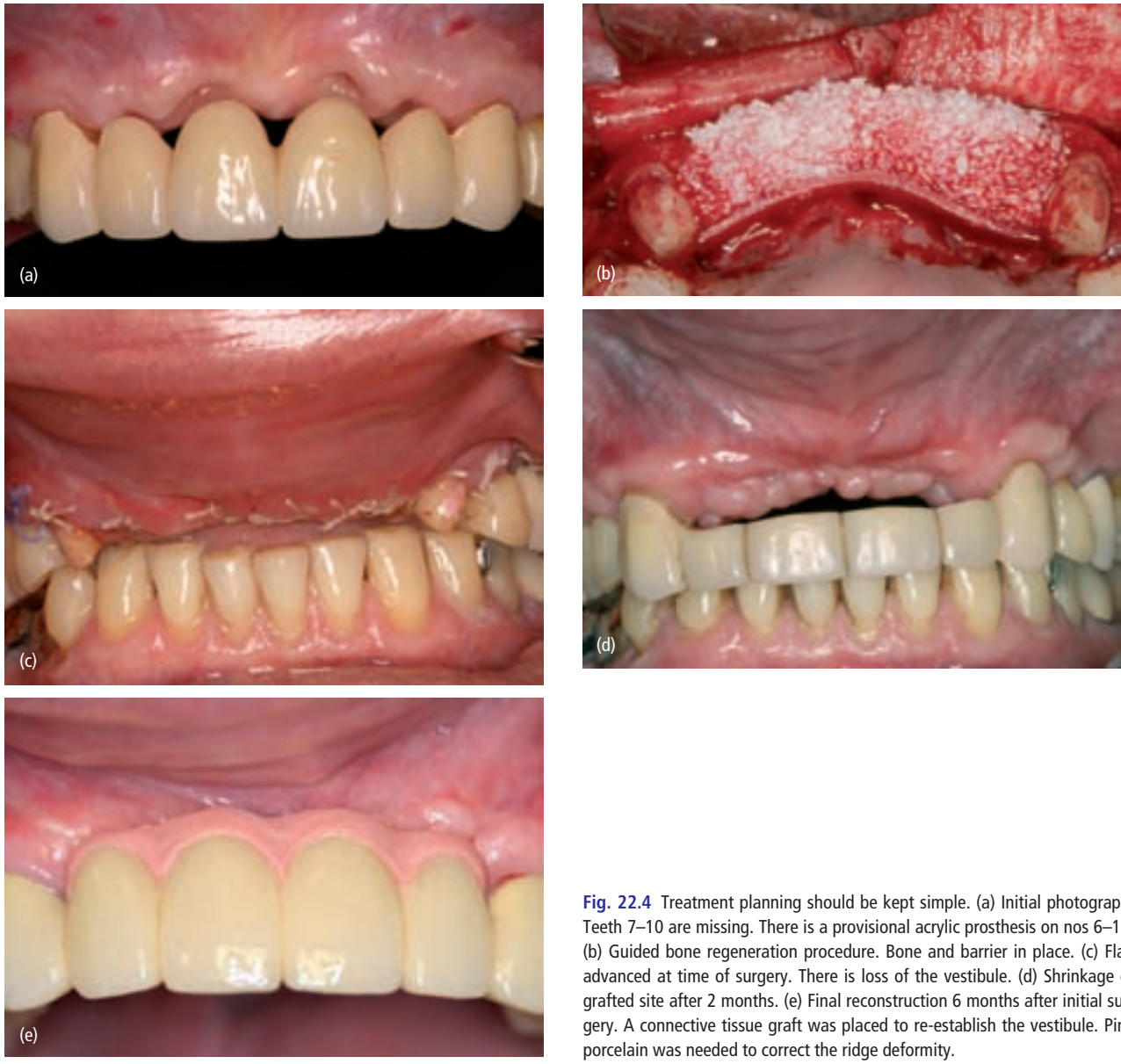


Fig. 22.4 Treatment planning should be kept simple. (a) Initial photograph. Teeth 7–10 are missing. There is a provisional acrylic prosthesis on nos 6–11. (b) Guided bone regeneration procedure. Bone and barrier in place. (c) Flap advanced at time of surgery. There is loss of the vestibule. (d) Shrinkage of grafted site after 2 months. (e) Final reconstruction 6 months after initial surgery. A connective tissue graft was placed to re-establish the vestibule. Pink porcelain was needed to correct the ridge deformity.

prosthesis required pink ceramics to obtain an acceptable esthetic result (Fig. 22.4e). Currently, vertical ridge augmentation is not predictable and since this patient had a low smile line, it would have been advisable to have initially planned to use pink porcelain. It should be noted that pink porcelain supplies a prosthetic substitution for missing soft and hard tissues as an option for individuals who are not candidates or do not accept a surgical option to rebuild reduced ridges. Furthermore, in many cases pink porcelain may be needed to provide lip support in the esthetic zone.

Case 5: Labial concavity on the buccal tooth of site 8

Etiology

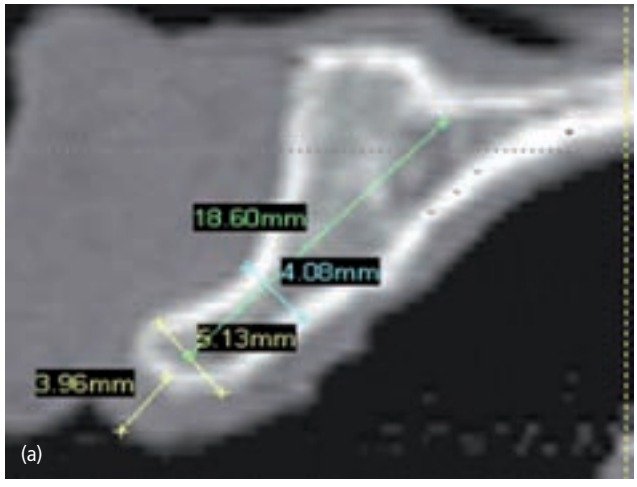
Restoration of an anterior edentulous space in a patient with a high smile is an esthetically demanding procedure that requires careful treatment planning. The patient in Fig. 22.5(a, b) presented with tooth 8 missing. Probing the adjacent teeth revealed that the proximal surfaces had normal attachment levels, which has been shown to be the critical determinant in ensuring that the papilla height is bilaterally maintained interproximally (9). However, the CT scan indicated that there was a narrow ridge with a labial concavity (Fig. 22.5a).

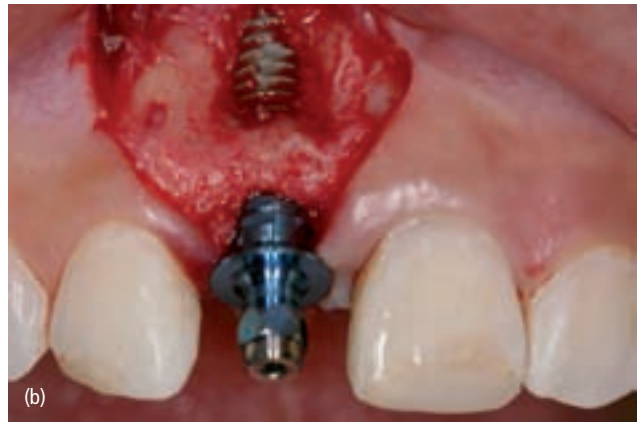
Prevention

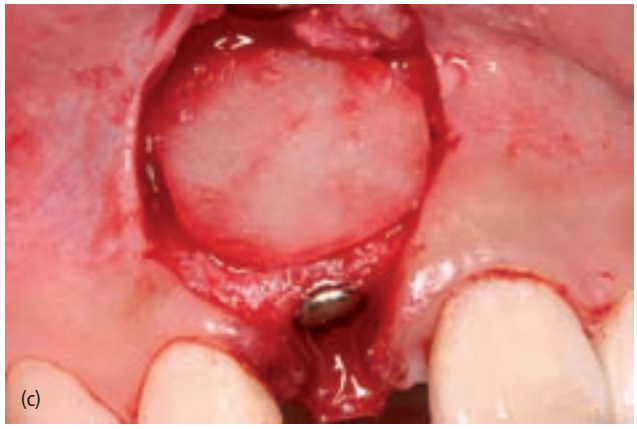
To avoid an esthetic dilemma there are several strategies that can be employed: retention of tooth 8, socket preservation surgery with delayed implant placement, or ridge augmentation after healing of the extraction site before implant placement.

Treatment

Simulated implant placement revealed that a buccal plate fenestration would be created upon implant placement. This occurred when the implant was inserted. (Fig. 22.5b) Treatment at the time of implant placement included placement of a bone graft and a collagen barrier on the buccal aspect (Fig. 22.5c). After 4 months of heal-







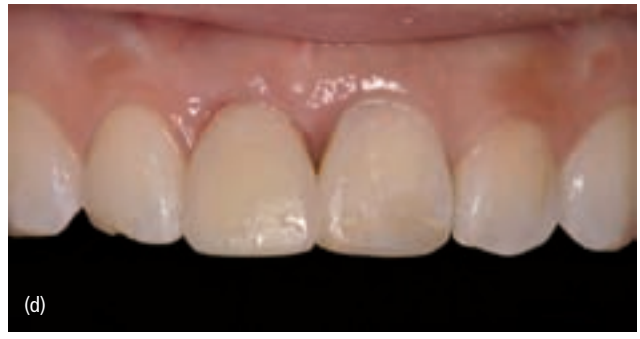


Fig. 22.5 Treatment planning a problematic case at site 8. (a) CT scan demonstrating lack of buccal bone. (b) Implant placement creating expected buccal fenestration of bone. (c) Barrier positioned over the bone graft. (d) Restoration in place 5 months after implantation. (Courtesy of Dr Tai.)

ing the horizontal improvement in the buccal contour was evident and the provisional crown demonstrated good esthetic contour (Fig. 22.5d).

Case 6: Misleading radiograph: graft material looks like root tips

Etiology

A patient presented desiring an implant at site no. 30. The soft tissue looked normal and the radiograph revealed what appeared to be two roots left within the alveolus (Fig. 22.6a). The tooth had been extracted by another clinician 3 months before the current examination.

Prevention

Socket preservation consisting of thorough débridement and graft placement combined with a barrier membrane facilitates healing of an extraction site. The clinician placing the implant should be aware of prior treatment including the time of healing and materials used during the socket preservation procedure.

Treatment

Upon flap reflection, a spoon excavator was used to determine whether bone had encased the roots. This revealed that the roots were not present and the bovine anorganic bone particles were partially removed from the distal root area (Fig. 22.6b). The graft had healed with a fibrous seam, giving the impression that there was a periodontal ligament around the retained roots. The graft had only partially calcified (10). An implant will be placed in this location. However, the proper positioning of the implant will require removal of any loose graft particles and drilling into the interradicular bone without slipping into the mesial or distal root areas.

Case 7: Improper angulation of X-rays can provide misleading information

Etiology

At sites 20 and 21 an X-ray appeared to show that the implants were placed with a distal inclination (Fig. 22.7a).

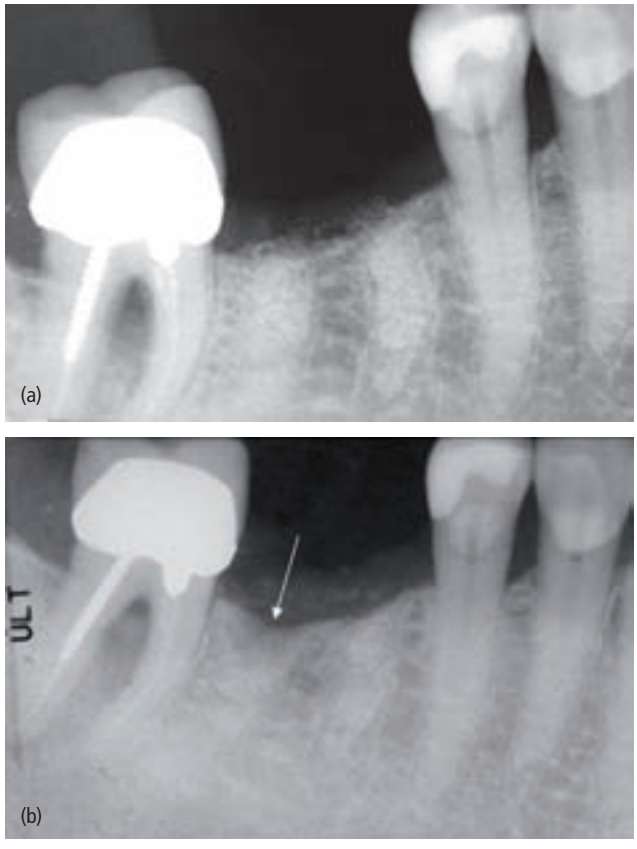


Fig. 22.6 Misleading radiograph: graft material looks like root tips at site 30. (a) Initial radiograph. There appeared to be roots left in the bone at site 30. (b) Postoperative radiograph. Bovine anorganic bone was partially removed at the distal root site. The graft had a fibrous seam around the healed extraction site.

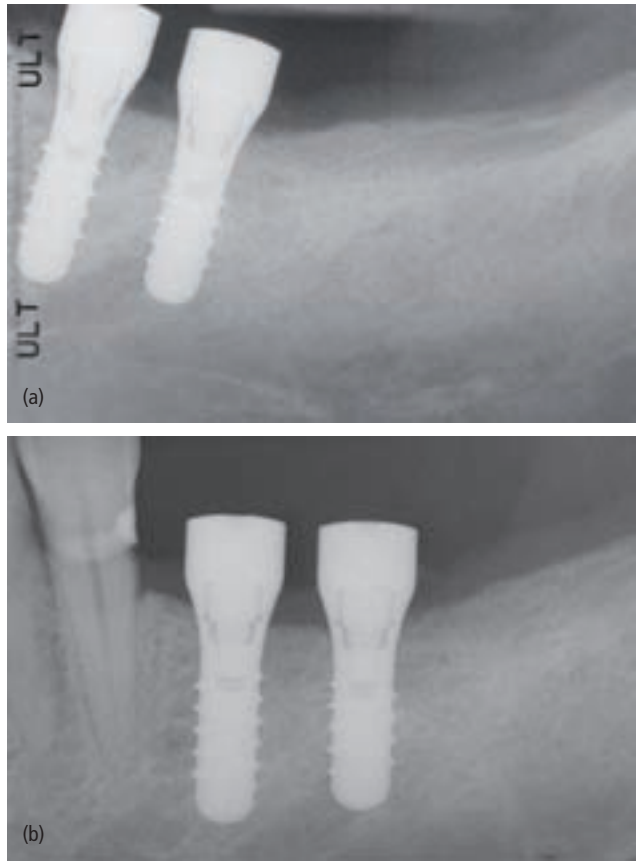


Fig. 22.7 Angulation of X-rays can provide misleading information. (a) Initial radiograph gives the appearance at sites 20 and 21 that there was pronation of the wrist upon implant insertion. (b) Corrected angulation of radiograph indicated that the implants were placed straight.

Prevention
This could be prevented with a proper X-ray paralleling technique.

Treatment
The radiograph was retaken and the X-ray beam directed perpendicular to the film. The second radiograph indicated that the implants were placed in proper parallel position and caries was noted distally on tooth 22 (Fig. 22.7b).

Case 8: Misleading radiograph endangering an implant

Etiology
A patient presented with a radiograph that appeared to indicate that the implant (site 19) (Fig. 22.8a) contacted the adjacent tooth (no. 20).

Prevention
This could be prevented with a proper X-ray paralleling technique.

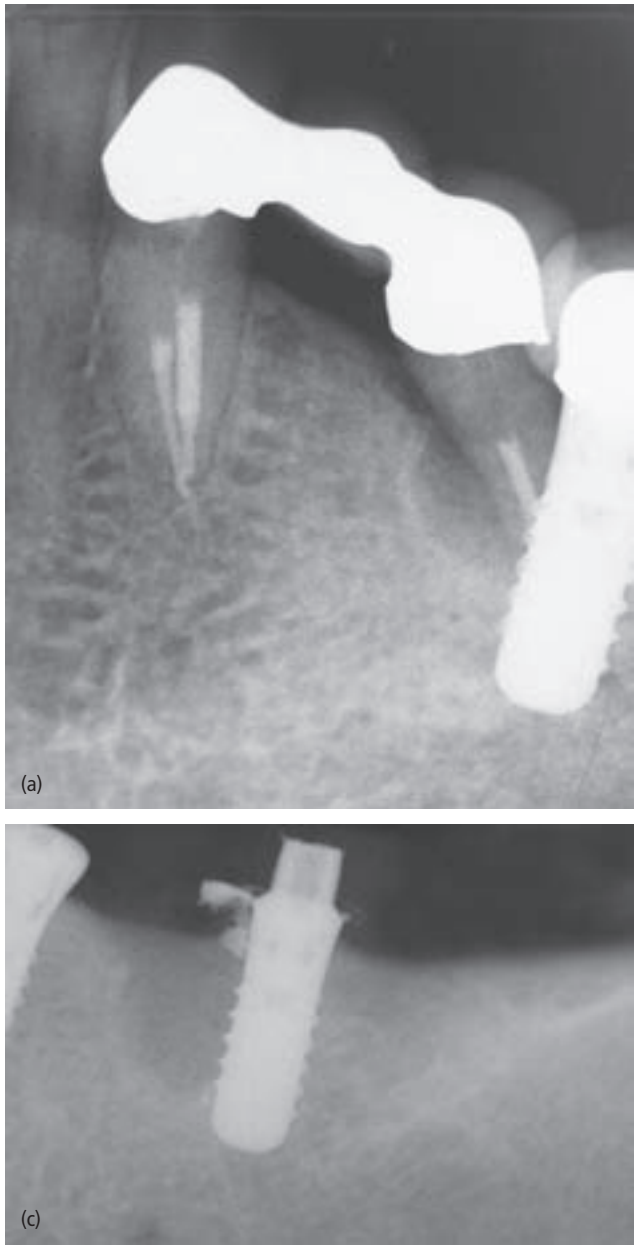


Fig. 22.8 Misleading radiograph endangering an implant. (a) Initial radiograph of what appears to be an implant overlapping a tooth at site 20. (b) Corrected angulation of radiograph indicates that the tooth and implant do not touch. (c) Infected tooth 20 was removed. (d) Three months postoperative healing. The defect adjacent to the implant has resolved.

Treatment

An additional film revealed that the implant was 2 mm away from the tooth (Fig. 22.8b). Caution must be exercised when taking radiographs to avoid superimposing the implant onto the adjacent teeth. This is particularly true in the cuspid area where the arch is turning and the film is usually slanted. The latter radiograph of tooth 20 revealed a severe osseous defect and aided in determining that the tooth required removal, because the pathosis was endangering the implant at site 19 (Fig. 22.8c). The tooth was extracted and no grafting was performed. Figure 22.8(d) reveals complete healing after 3 months and there were no significant probing depths adjacent to the implant. Ideally, if there was pathosis related to tooth 20, the tooth should have been removed before implant placement.

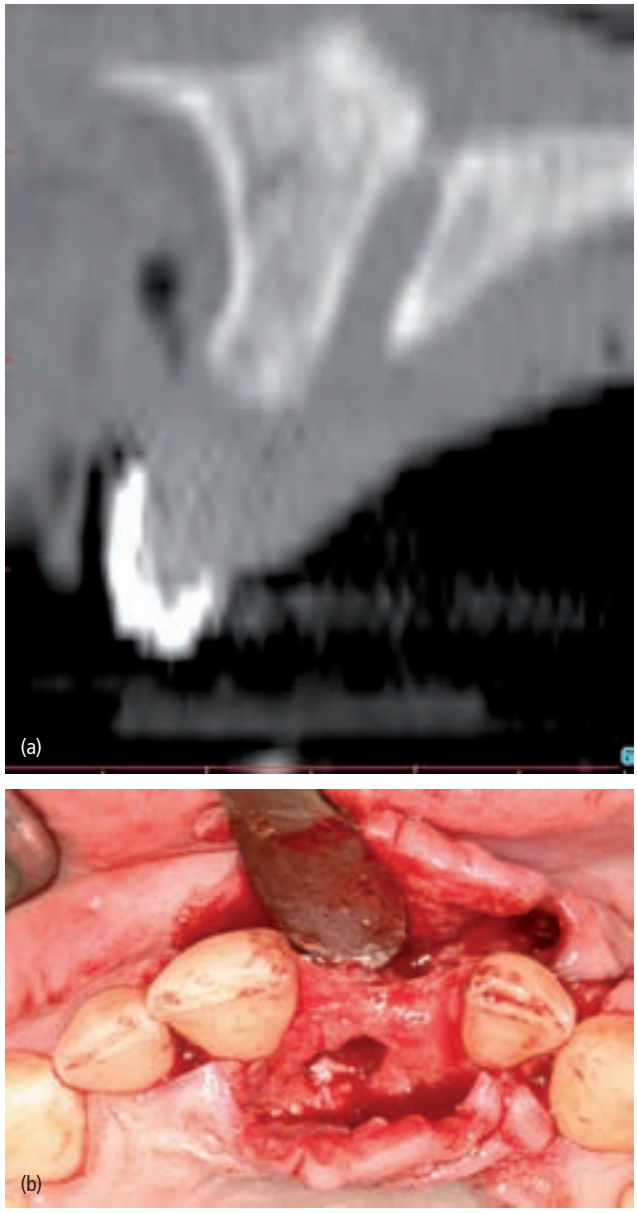
Case 9: Avoiding entry into the nasopalatine foramen

Etiology

This problem relates to the presence of a nasopalatine foramen. The nasopalatine canal (mean 8.1 mm long) exits the incisive foramen (Fig. 22.9a) (11). Within the foramen, two incisive canals are often observed at the level of the nasal floor. However, one to four canals may be seen. At the level of the nasal fossa the mean width of the canal is 4.9 mm and at the crest of the ridge the incisal foramen is usually found 7.4 mm from the buccal plate of bone (Fig. 22.9b) (11).

Prevention

The canal should be avoided.



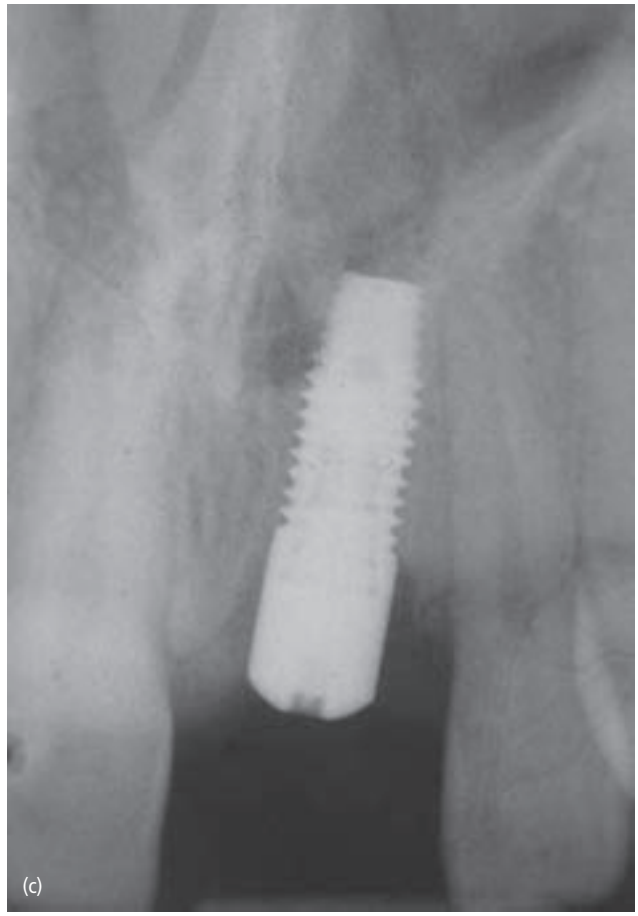


Fig. 22.9 Avoid or enter the nasopalatine foramen between sites 8 and 9. (a) CT scan of the nasopalatine canal. (b) Clinical exposure of the nasopalatine canal. (c) Implant placed at site 9 avoiding the nasopalatine canal.

Treatment

If there is a large canal, Artzi *et al.* (12) suggested displacing its contents (without elimination) and inserting an implant. Rosenquist and Nystrom (13) advocated enucleating the canal and placing a bone graft. A large incisive canal is demonstrated in Fig. 22.9. It was decided to avoid placement of the implant into the canal (Fig. 22.9c). This was done to obviate the need to perform a bone graft and to avoid the possibility of inducing nerve damage with subsequent numbness lingual to the central incisor teeth.

Case 10: Avoiding a paresthesia in the mental foraminal area

Etiology

This complication is caused by damage to the mental nerve.

Prevention

If there is uncertainty concerning the position of the mental foramen or the amount of bone coronal to it, the roof of the mental foramen should be exposed and a measurement taken from the crest of the ridge to the roof of the foramen (Fig. 22.10a) (14). Furthermore, it should be considered that the mental canal emerges at an average emergence angle of 50 degrees (range 11–77 degrees) (15) and that the roof of the foramen is approximately 1–2 mm more coronal than where the inferior alveolar nerve traverses the mandible. Thus, there is an additional safety factor in this region when measurements are taken to the roof of the foramen.

Radiographs are inaccurate in depicting the presence of an anterior loop of the mental nerve (Fig. 22.10b). Therefore, if there is concern that one is present, it is advisable to verify this in two ways (Fig. 22.10c). Clinically, a Nabers probe may be gently placed into the distal aspect of the foramen to avoid causing nerve damage. If the canal is patent there is no anterior loop. If it is occluded there is an anterior loop. However, this probing does not provide information as to the length of the anterior loop. The other, less invasive method is to obtain a CT scan to determine the position of the inferior alveolar nerve and the mental foramen. If teeth are not present to provide a landmark related to the location of the foramen, a radiographic guide with markers should be used to help delineate its location.

Treatment

Without a CT scan, it is prudent to follow the recommendations by Solar *et al.* (15) and place the distal aspect of an implant 6 mm anterior to the foramen. However, if there is any uncertainty pertaining to the location of the nerve a CT scan should be ordered.

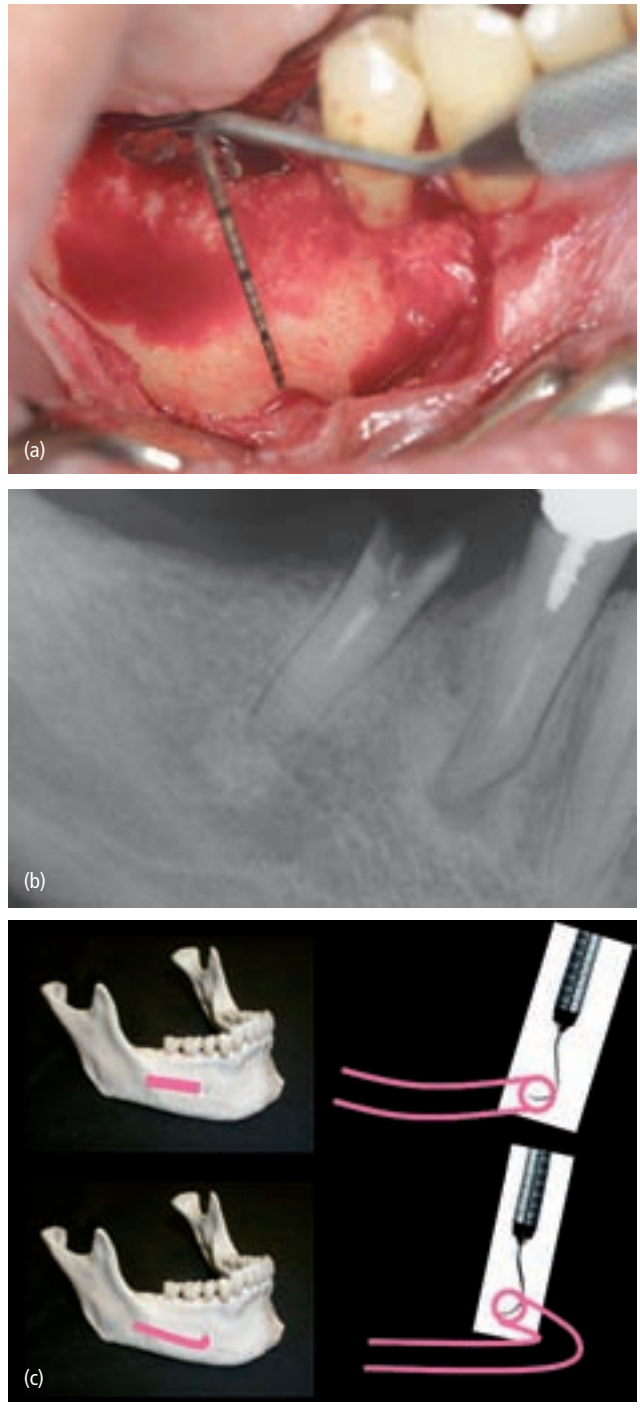


Fig. 22.10 Avoiding a paresthesia in the mental foraminal area. (a) Mental foramen exposed at site 29. Measure the distance from alveolar bone crest to the mental foramen with a periodontal probe. (b) Anterior loop of the mental foramen apical to tooth 29. (c) If placement of the probe into the mental foramen on the distal side reveals that the mental canal is patent, then the anterior loop is not present. If placement of a probe into the mental foramen on the distal side reveals that the mental canal is not patent, then an anterior loop of the mental nerve exists. The nerve traversed inferiorly and looped back to the foramen creating an anterior loop. (Reprinted with permission from *J Periodontol* (14).)

Case 11: Abscessed tooth: immediate or delayed implant placement

Etiology

The patient presented with an abscessed tooth at site 5 (Fig. 22.11a). Endodontic treatment had been completed 4 weeks before patient presentation. There was an abscess (with exudate) on the mesial surface and the probing depth measured 12 mm. The patient had been taking amoxicillin (500 mg three times a day) for 1 week. The normal width of a first bicuspid at the cementoenamel junction (CEJ) is 4.8 mm, while 2 mm below the CEJ it is 4.2 mm (16). Therefore, to obtain primary stability the implant must penetrate apically into native bone.

Prevention

Thorough débridement of a tooth-related infection is recommended before immediate implant placement.

Treatment

Placement of a 4.1 mm implant posed the risk of the implant not attaining primary stability. The patient was ultrasonically débrided to obtain drainage and continued on amoxicillin for one more week. The tooth was then extracted and a 14 mm implant placed. The implant healed without any complications (Fig. 22.11b). Casap *et al.* (17) also noted successful therapy with immediately placed implants in patients presenting with dentoalveolar infections, provided thorough débridement of the granulomatous tissue and bone is performed before implant placement.

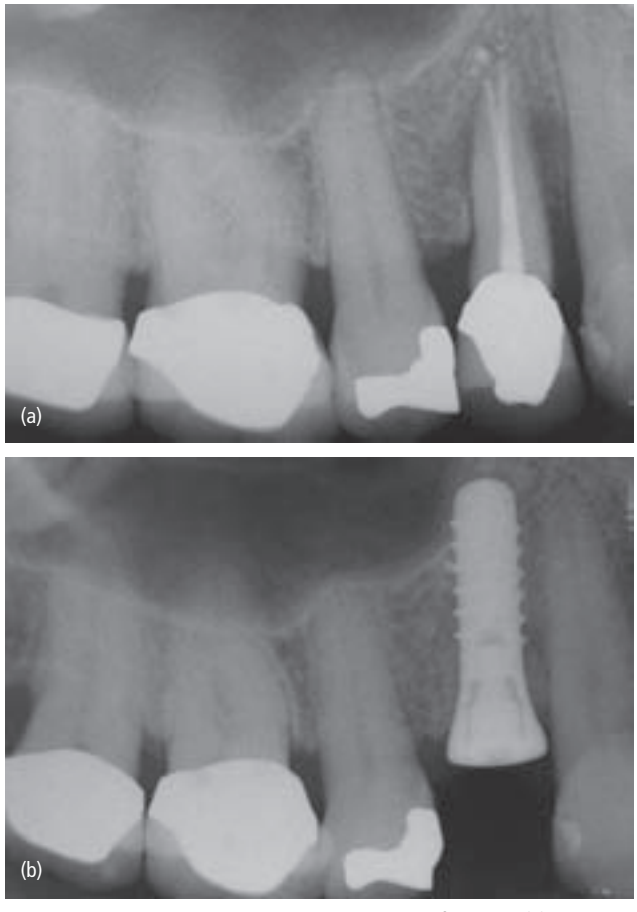


Fig. 22.11 Abscessed tooth: immediate placement of implant. (a) Tooth 5 is fractured and abscessed. There is a radiolucency along the root. (b) Tooth 5 was extracted and an implant was immediately placed that engaged the bone apically and laterally.

Case 12: Accommodating a 12 mm mesiodistal space between teeth

Etiology

The question arises as to how large a space can be accommodated by one large implant or combination of implants.

Prevention

Careful measurements and planning must be performed to accommodate a mesiodistal edentulous space before initiating an osteotomy.

Treatment

The following recommendations are made with respect to implant spacing. If there is 14 mm space mesiodistally, two standard implants (4.1 mm width) can be placed leaving 1.5 mm between the tooth and the implant and 3 mm between the implants. If there is 12 mm space mesiodistally, placement of one 4.6–5.0 mm implant with a large platform (6–6.5 mm) is recommended. (Fig. 22.12). If there is a 13 mm space, one standard and one narrow diameter implant, or two narrow diameter implants (≤3.3 mm) can be placed. A crown that is too large when placed on a standard implant can result in screw or implant fracture. This can occur owing to increased occlusal forces in the posterior maxilla or mandible, especially in patients exhibiting a parafunctional habit.

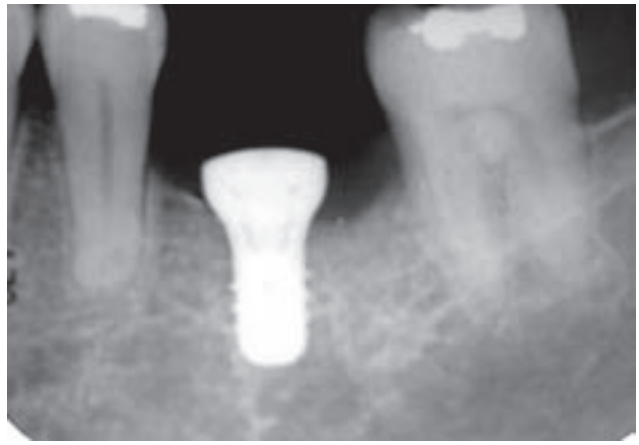


Fig. 22.12 Lack of mesiodistal space. A wide neck implant (platform 6.5 mm) inserted to accommodate a 12 mm mesiodistal space between teeth 20 and 18.

Involved tissues: soft tissue, bone, and nerves

Soft tissue

Case 13: Soft-tissue pain after implant insertion

Etiology

A patient presented for implant placement at sites 21, 19, and 18. There was an implant with an abutment present at site 20, and a broken, submerged implant at site 17. It was difficult to determine clinically whether there would be sufficient ridge width to place all three implants. Furthermore, site 21 had an apparent osseous defect caused by partial loss of the buccal plate of bone. Therefore, the patient was sent for a CT scan to obtain additional diagnostic information. The CT scan confirmed that part of the buccal plate was missing at site 21 (Fig. 22.13a) and that the mental foramen emerged at site 19 (the first molar) (Fig. 22.13b). Implants were placed at sites 21, 19, and 18 (Fig. 22.13c). The missing buccal plate on no. 21 was treated with bovine anorganic bone and a barrier membrane. The procedure took place without complication. Three days later the patient called and reported that she was in extreme discomfort and was taking pain medication every 2.5 hours. There was concern that an implant may have caused compression of the bone over the mental foramen, the guided bone procedure on no. 21 was infected, or the flap had separated along the suture line. When the patient presented the next day, it was apparent that her pain was caused by a dehiscence along the suture line.

Prevention

The patient should be instructed to avoid brushing and masticating on the side of the mouth where surgery was performed in order to avoid creating a soft-tissue dehiscence and lodging food under the flap.

Treatment

The patient, despite being told to use a rinse for oral hygiene in the surgical areas, decided to brush the incision line. Her pain after surgery at a site that was initially comfortable was caused by flap dislodgment, which then moved during jaw movement. The site was irrigated thoroughly, anesthetized, and resutured, and all symptoms disappeared.

Case 14: Sloughing of palatal tissue after harvesting a connective tissue graft

Etiology

The palate is the usual donor site for autogenous connective tissue grafts. The palatal tissue on average is 3–6 mm thick and increases in thickness when proceeding anterior to posterior (18). In the present case, subsequent to harvesting a subepithelial connective tissue graft to increase the thickness of the buccal tissue around a maxillary anterior implant, part of the palatal flap necrosed (Fig. 22.14). This can occur owing to thinness of the flap margin, flap perforation, or pressure necrosis caused by suturing under tension.

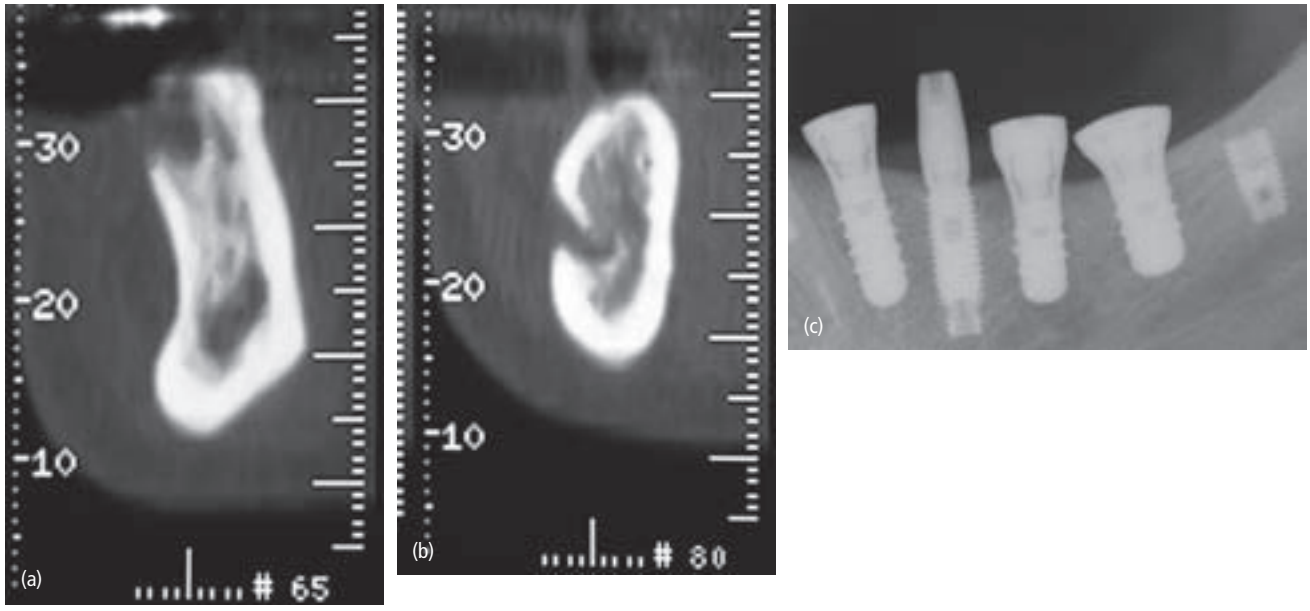


Fig. 22.13 Soft-tissue pain after implant insertion. (a) CT scan demonstrating damage to the buccal plate of bone at site 21 requiring a guided bone regeneration procedure. (b) The mental foramen was located by tooth 19. (c) Implants inserted at sites 21, 19, and 18. Implants 20 and 17 were previously there. The implant at 20 was to be used and 17 was left submerged.

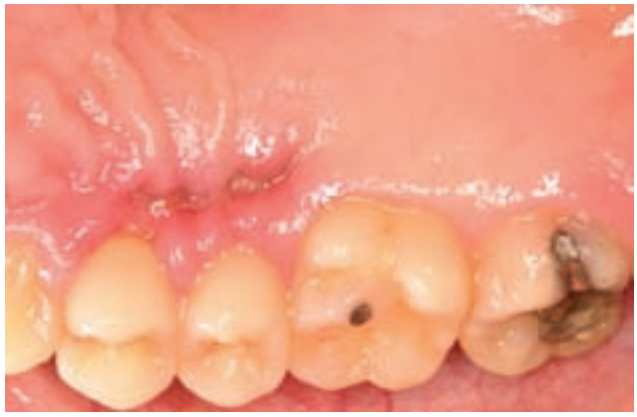


Fig. 22.14 Soft-tissue sloughing. Sloughing of tissue associated with harvesting a connective tissue graft. The palatal flap was too thin and the tissue necrosed.

Prevention
Measure the soft-tissue thickness of the palate after local anesthesia by sounding with a probe perpendicular through the tissue to bone to ensure that there is an adequate amount of tissue for the graft. Avoid thinning the flap too much and suturing under tension.

Treatment
If the site is painful, place Surgicel over the wound and cover it with dental cyanoacrylate (PeriAcryl, GluStitch, Delta, BC, Canada). Another technique to enhance patient comfort is to fabricate a vacuum-formed template on a model before surgery, reline it after surgery with a soft-tissue material (e.g. Coe Soft; GC America, Alsip, IL, USA), and advise the patient to use it until the palatal wound heals or is asymptomatic.

Case 15: Recession or a dehiscence creating an esthetic dilemma

Etiology
A common cause of buccal gingival recession is placement of the implant too far to the buccal. If a patient presents with a high smile line (or is esthetically demanding regardless of the lip line), immediate removal of a malpositioned implant during surgery and placement of another one in proper position, or removal of the implant followed by GBR to restore gingival contour are strategies that may avoid numerous attempts at bone and/or soft-tissue grafting to achieve an acceptable esthetic result around a malpositioned integrated implant. Following regeneration of the tissues, placement of another implant in the proper position will facilitate achieving an esthetic final result.

Prevention
Surgical planning with a CT scan can ensure that there is adequate bone for implant insertion. An implant should be placed with a surgical guide in a site where there is adequate keratinized gingiva. In addition, the implant should be placed apically to provide adequate running room to compensate for changes in the position and diameter of the implant as it transitions into the clinical crown.

Treatment
After implant integration in the maxillary anterior region, subsequent recession is difficult to correct (Fig. 22.15a). Subepithelial connective tissue grafts and coronally positioned flaps placed on the buccal aspect are possible, but do not provide predictable solutions. One technique that can be used to treat this problem includes removal of the crown and the abutment, insertion of a cover screw, and submerging the implant by placing a connective tissue graft (Fig. 22.15b–d). The graft should be placed with its borders under the adjacent tissue. Subsequently, a stage 2 procedure is done and the implant is uncovered and restored. If implant threads are exposed, the situation is more difficult to correct. The above procedure should be performed to restore the soft tissue. Then, following soft-tissue healing, a bone graft and a barrier membrane (GBR) can be placed in an attempt to regenerate missing bone.

These attempts at correcting this type of problem usually require multiple surgical procedures and at times do not produce the desired results. Therefore, removing an implant immediately after noting that it has been inserted incorrectly is a more predictable strategy for the patient and clinician. It is less costly and less painful, and provides a more prudent and esthetic solution than trying to correct a problem after an implant is integrated. Placing an abutment or a transfer coping on the implant after insertion is a method of visualizing whether the implant is too far to the buccal. If it is, immediate removal and reangulation (if possible) will obviate the above problems. If the implant cannot be placed in a proper restorative position, a GBR procedure should be performed and the implant placed at a future time following the healing response.

Case 16: Tissue emphysema

Etiology
Tissue emphysema is caused by inadvertent propulsion of air into tissues under the skin or mucous membranes. Air from a high-speed handpiece, air/water syringe, air polishing unit, or air abrasive device can be projected into a sulcus, surgical wound, or laceration in the mouth (Fig. 22.16). The air can follow the fascial planes and create a unilateral enlargement of the facial and/or submandibular regions. When the skin or distended mucous membranes are felt, they frequently produce a crackling sensation (crepitus) as the gas is pushed through the

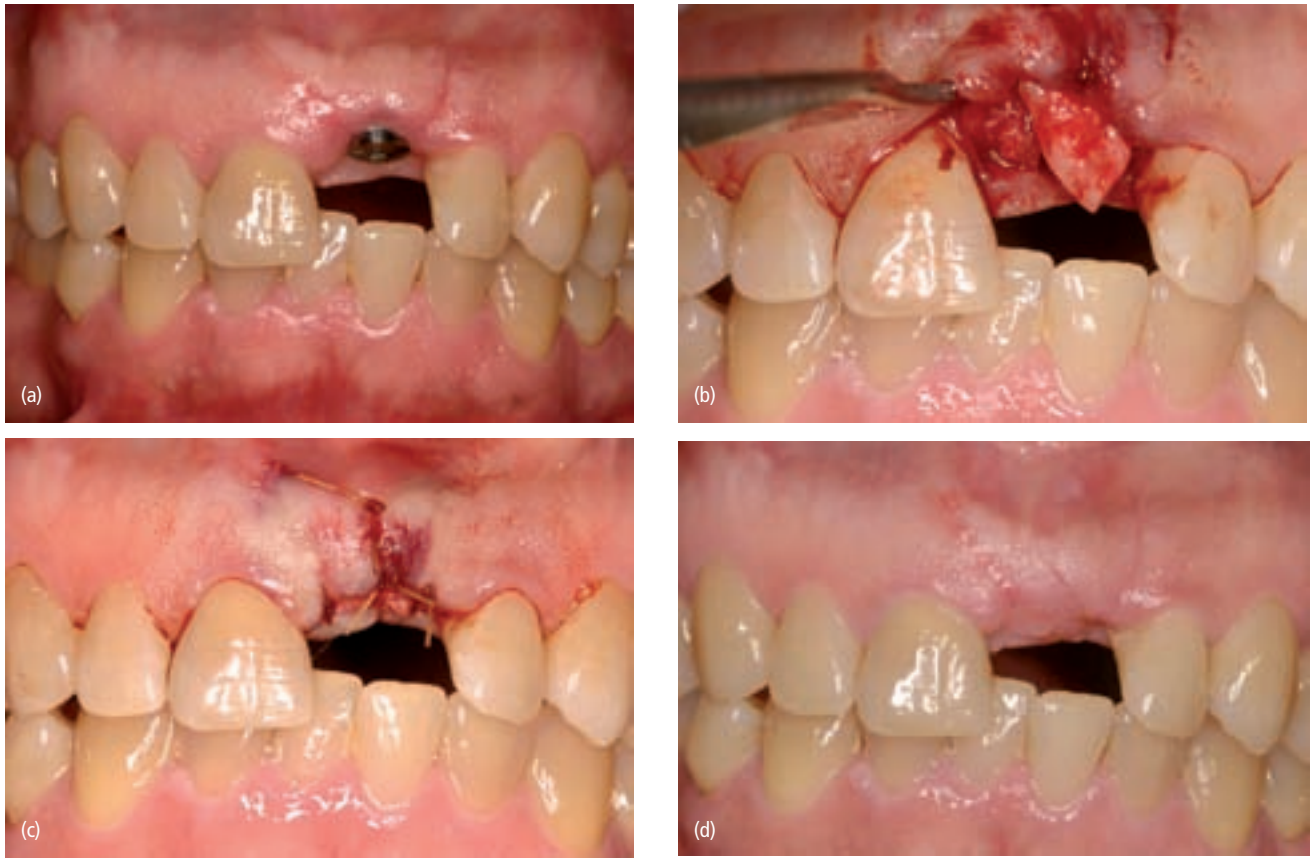


Fig. 22.15 Recession or a dehiscence: creating an esthetic dilemma. (a) Initial photograph on an implant with recession at site 9. (b) After flap exposure, a connective tissue graft was placed over the implant and the flap was advanced to cover the graft. (c) Primary flap closure. (d) Healing after 1 month.

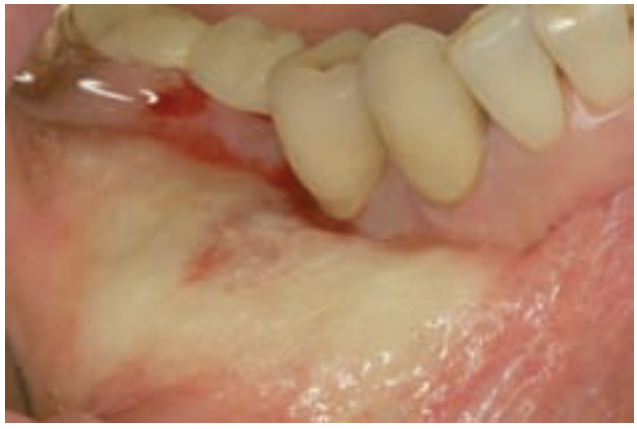


Fig. 22.16 Emphysema air from a high-speed handpiece induced an emphysema at sites 27 and 28. (Reprinted with permission from *J Periodontol* (19).)

tissue. The crackling sound is pathognomonic for tissue emphysema even when discomfort is not reported.

Prevention
For procedures involving extensive drilling and shaping of bone, use of a handpiece which propels only sterile water and expresses air in a retrograde manner is recommended. In addition, when using an air abrasive, the tip should not be pointed into the sulcus. Furthermore, air abrasives should not be used in highly inflamed tissues that have friable marginal tissues.

Treatment
Therapy for tissue emphysema usually includes antibiotics and mild analgesic therapy, close observation, saline rinses, light massage, heat packs, and reassurance. Antibiotics are given because bacteria may have been projected into the tissue with the compressed air. Symptoms usually dissipate in 3–10 days.

Bone

Case 17: Tapered ridge can be misleading

Etiology
Crestal resorption of the bone after teeth are extracted can result in a narrow ridge buccolingually, especially at the crest. The patient in Fig. 22.17 presented with a visually narrow ridge in the mandibular left posterior area. There was concern that the ridge was too thin for placement of implants, based on clinical visualization of the ridge.

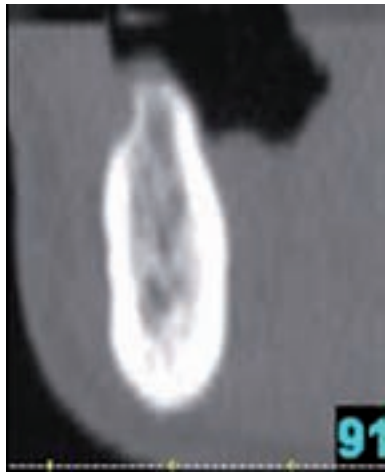


Fig. 22.17 Tapered alveolar ridge. At an implant site the bone often gets wider apically. Therefore, the initial appearance of a ridge may be misleading.

Prevention

Timely insertion of implants after teeth are extracted helps avoid additional bone resorption over time, but does not avoid bone loss when teeth are extracted. Schropp *et al.* (20) reported an average of 50% loss of bone width 1 year postextraction. Most of this loss took place within the first 3 months. Socket preservation at the time of extraction can help maintain ridge morphology (7, 8, 21).

Treatment

Palpation of the ridge revealed that it appeared to widen apically. After administration of local anesthesia, bone thickness was evaluated using a ridge mapper (Salvin Dental Specialties, Charlotte, NC, USA). There appeared to be enough bone width for implants. However, for a more accurate diagnosis, the patient was sent for a CT scan. It demonstrated that there was 15 mm of bone height from the crest of the ridge to the inferior alveolar canal (Fig. 22.17). The scan also indicated that the mandibular ridge was 2–3 mm wide for the first 5 mm, which was too narrow for a standard implant placement. However, beyond the apical distance of 5 mm, the thickness of bone increased to 6 mm. Upon flap reflection, the ridge was plastied with a bur and 4.1 wide by 8 mm long implants were placed within the bone, leaving a 2 mm safety distance from the inferior alveolar canal. Another treatment option when there is a narrow buccolingual volume of bone coronal to the inferior alveolar canal is to place an implant in enough bone to attain primary stability, while leaving 2 mm for safety distance to the nerve. Several millimeters of the coronal aspect of the implant will then be left (high) out of the bone. Vertical bone augmentation is attempted by placing bone and a membrane, thereby submerging the exposed threads. This strategy, if performed properly (see Chapters 13 and 14) is predictable, since the exposed implant serves as a "tent pole" creating space for new bone formation and the implant provides a sterile surface for osseointegration.

Case 18: Loss of bone graft material attached to the gingiva

Etiology

Tooth 3 was symptomatic and had deep probing depths (Fig. 22.18a). It was diagnosed with a hopeless prognosis

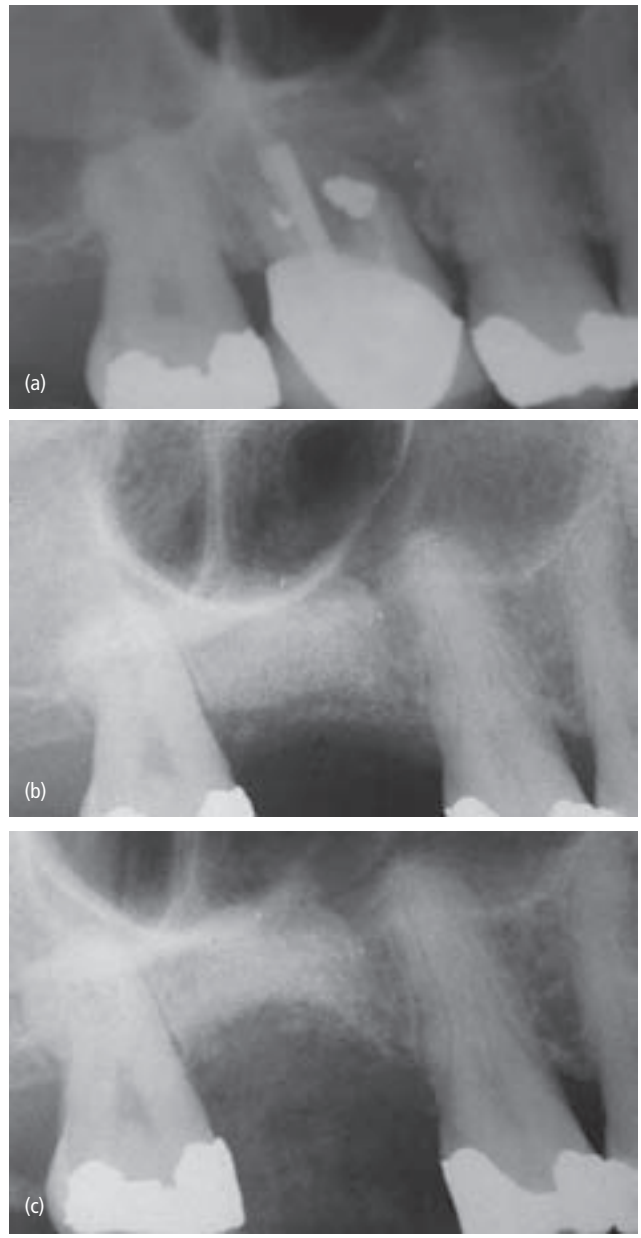


Fig. 22.18 Loss of bone graft material attached to the gingiva. (a) Initial radiograph of tooth 3. (b) The tooth was removed and bovine anorganic bone was placed and covered with a resorbable barrier. (c) Six months later when the flap was elevated, 3 mm of graft material was attached to the flap and left the ridge defective.

and was extracted. Bovine anorganic bone was placed in the socket and an absorbable barrier placed over the alveolus. Primary closure and coverage of the barrier was not attained. Healing was uneventful and a radiograph taken 6 months later was interpreted to indicate that the site was ready to receive an implant (Fig. 22.18b). However, upon flap reflection, 3 mm of the graft material remained attached to the flap and only 3 mm of bone was left subantrally (Fig. 22.18c).

Prevention
Placement of a barrier and not attaining primary closure in this compromised site resulted in incomplete calcification of the graft material. Primary closure should have been attained or the augmentation procedure should have been delayed until the gingiva healed and covered the socket. The additional gingiva would have facilitated attaining primary coverage of the barrier and graft material used to augment the ridge.

Treatment
It was determined that there was too little bone to attempt a sinus elevation using an osteotome. The patient was informed that a lateral window sinus augmentation would require waiting an additional 6 months. After consultation with the patient, it was decided to place a tooth-supported fixed prosthesis extending from tooth 2 to 4.

Nerves

Case 19: Mental foramen at crest of the bone

Etiology
Subsequent to extraction of teeth over the mental foramen, the bone resorbs and the mental foramen becomes positioned closer to the alveolar crest. As a consequence of severe resorption, the mental foramen and mandibular canal can often be found in close proximity to the crest of the ridge (Fig. 22.19a, b) (22).

Prevention
Teeth should be retained, whenever possible, over the mental foraminal area to circumvent bone resorption. In addition, socket preservation after extraction of teeth in the foraminal area is desirable.

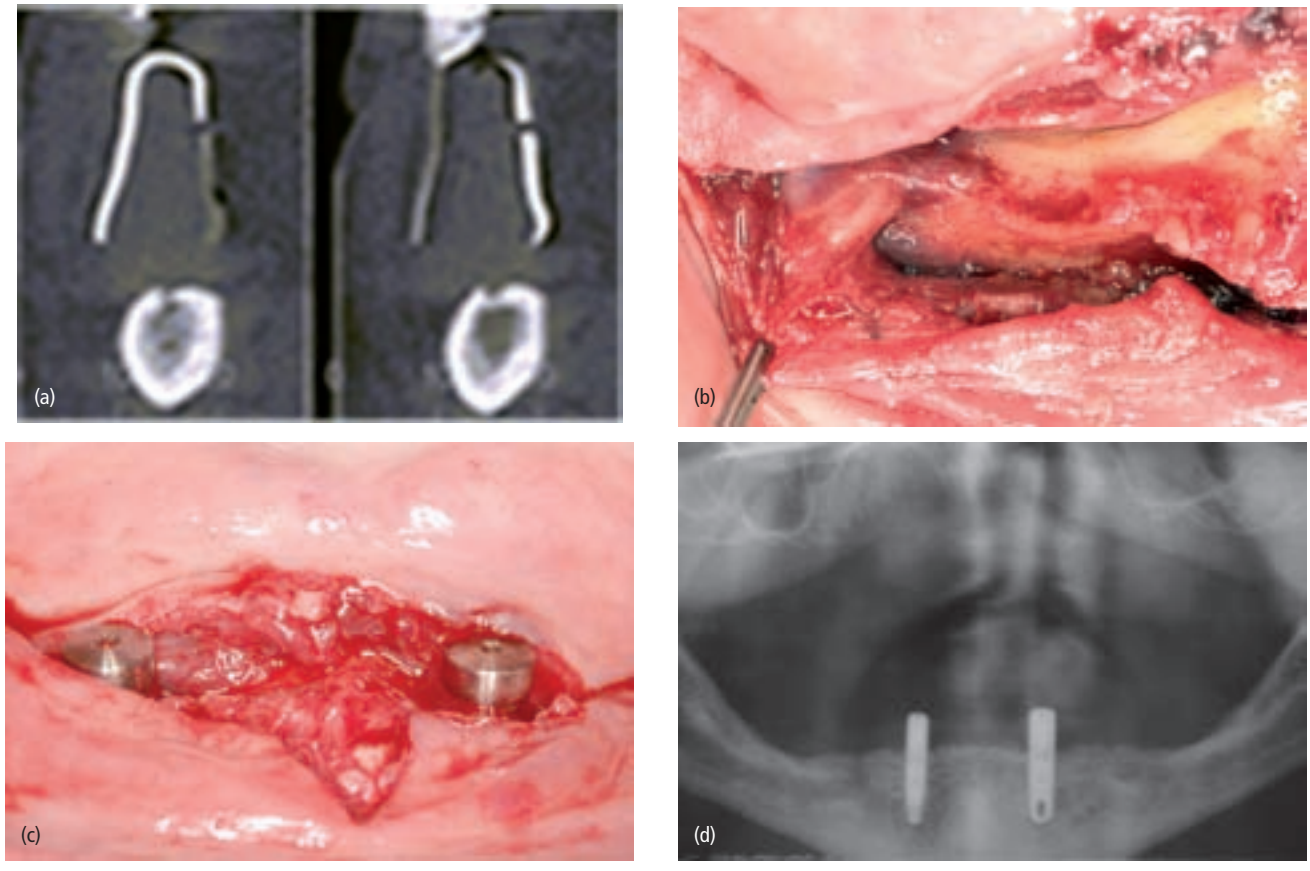


Fig. 22.19 Management of the mental foramen at the ridge crest. (a) CT scan demonstrating the location of the mental foramen at the ridge crest. (b) The mental nerve has been exposed to avoid injuring it during osteotomy preparation. (c) Implants were placed in the canine area. In general, in a mandibular edentulous arch, implants are placed 6 mm anterior to the metal foramen to avoid the possibility of hitting an anterior loop of the mental foramen if it is present. (d) Panorex demonstrating proper placement of implants at sites 22 and 27.

Treatment
Radiographs demonstrating the foramen close to the crest of bone dictate that the foramen should be surgically located before initiating an osteotomy to avoid nerve damage. Since the mental foramen is usually found on the buccal aspect of the ridge, it is prudent to make the crestal incision on the lingual aspect of the ridge to preclude inducing neurologic damage (23). Figure 22.19(c, d) demonstrates placement of implants at least 6 mm anterior to the mental foramen. Furthermore, in general, when severe resorption coronal to the mental foramen is noted, this area should be avoided as an implant site.

Case 20: Implants in inferior alveolar canal causing a paresthesia

Etiology
The patient in Fig. 22.20 presented with two excessively countersunk implants that were placed into the inferior alveolar canal in the mandibular left quadrant. The patient was pain free, but experienced paresthesia for several months before appearing for therapy.

Nerve injuries can be classified with respect to three levels of increasing severity (24). Neurapraxia connotes a minor injury that can be induced by compression or prolonged traction of the nerve. Because the axons are not altered, transitory loss of feeling is usually reversed within 4 weeks postsurgery (25). A more serious level is characterized by severe compression or traction of a nerve resulting in axonotmesis, which denotes intrafascicular edema, ischemia, or demyelination. There may be injury to a number of the axons; however, the general structure of the nerve is unaltered. Therefore, after this type of injury, feeling may return between 5 and 11 weeks and improve during the following 10 months (26). The most serious injury, neurotmesis, designates that no impulse can be propagated, because there has been disruption of the nerve.

Prevention
To avoid injuries to the inferior alveolar and mental nerves, their location must be ascertained. Assess periapical and panoramic films and apply the proper magnification correction factor, before development of an osteotomy. If required, a CT scan should be obtained. A security distance of 2 mm should be preserved between the whole implant body and any nerve canal (14, 27). Drill guards can be positioned on burs to prevent accidental overpenetration of the drill (27). It should also be remembered that the drill tip's length is not accounted for by the drill markings, thus many preparatory drills penetrate deeper than their markings indicate. For example, a "10 mm" marking on a 2 mm drill may actually penetrate 1 mm deeper when the marking is at a crestal level.

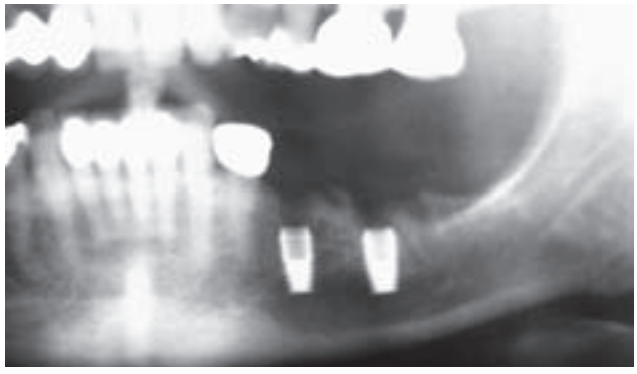


Fig. 22.20 Implants in the inferior alveolar canal.

Treatment
The treatment options were to retain the implants as sleepers, precluding replacement of teeth with a fixed implant restoration, or to plan for implant removal. The dilemma of leaving an implant in the canal is the possibility that it induces a traumatic neuroma (benign tumor) (28–30). Neuromas can form at the end of injured nerve fibers after nerve injury. These lesions occur as a result of unregulated nerve regeneration and often are painful.

The decision was made to remove the implants. Furthermore, since transection of the nerve requires microsurgical intervention and the prognosis for recovering sensation is poor (30), the patient, after consultation with an oral surgeon, decided not to pursue any additional therapy.

Point of information: It is important medicolegally to record the location and depth of neurosensory dysfunction after a nerve injury. The extent of the affected area should be documented and photographed or drawn and the outline kept in the patient's chart to monitor progress (26). In general, numbness for 16 weeks suggests that the nerve sheath was disrupted and the patient should be referred for consultation regarding nerve repair (24).

Implant placement

Case 21: Using a palatal slope for the implant overdenture

Etiology
The patient presented with a thin maxillary ridge (Fig. 22.21). The individual was to receive four implants for a maxillary overdenture.

Prevention
Retention of the dentition and atraumatic extraction of teeth to preserve the buccal plate of bone will decrease physiologic bone resorption. In general, extractions should be performed without flap reflection whenever possible.

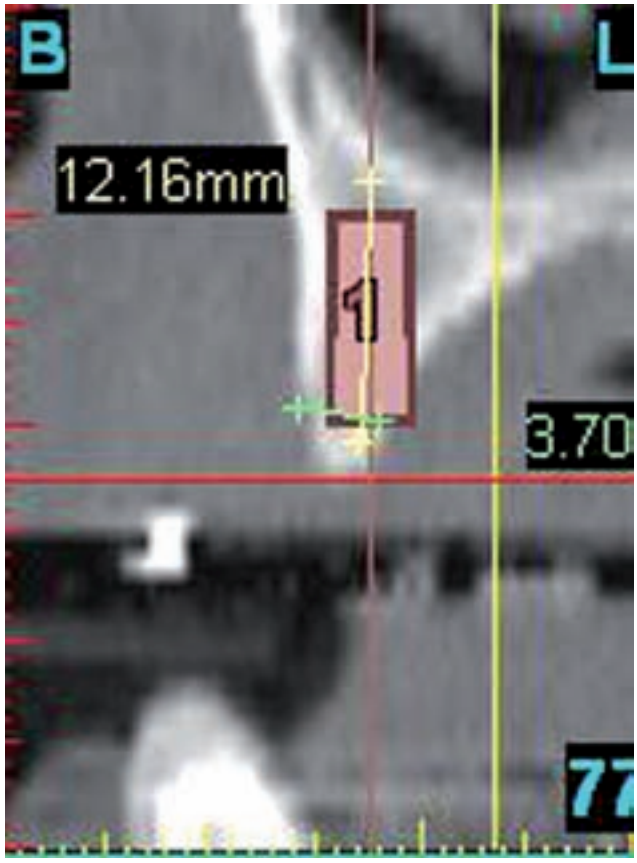


Fig. 22.21 Use of the palatal slope for the implant placement in preparation for an implant overdenture. Implants are placed palatal to the buccal plate of bone. It is desirable to maintain the integrity of the buccal plate. Threads of the implants out of the bone will be protected by the thick keratinized tissue.

Treatment

Options to manage the thin ridge included expansion of the ridge, a GBR procedure, or use of the palatal slope of the bone for implant placement (31). Implants were placed in a manner to avoid a dehiscence of the buccal plate of bone. Exposure of several threads on the palatal aspect of the implant was deemed acceptable, since all other surfaces of the implant were embedded in bone and there was good primary implant stability. The palatal aspect had thick keratinized tissue, which helps avoid recession. If more threads were exposed at the time of implant placement, a GBR procedure would have been performed to attain horizontal ridge augmentation.

Case 22: Weakest time for implant stability is 2–4 weeks postplacement

Etiology

The patient presented with a mobile tooth 4, which had a large radiolucency on its mesial and apical aspects (Fig. 22.22a). The tooth was extracted and the lesion was débrided. A 14 mm implant was inserted, which achieved primary stability (Fig. 22.22b). The implant was placed

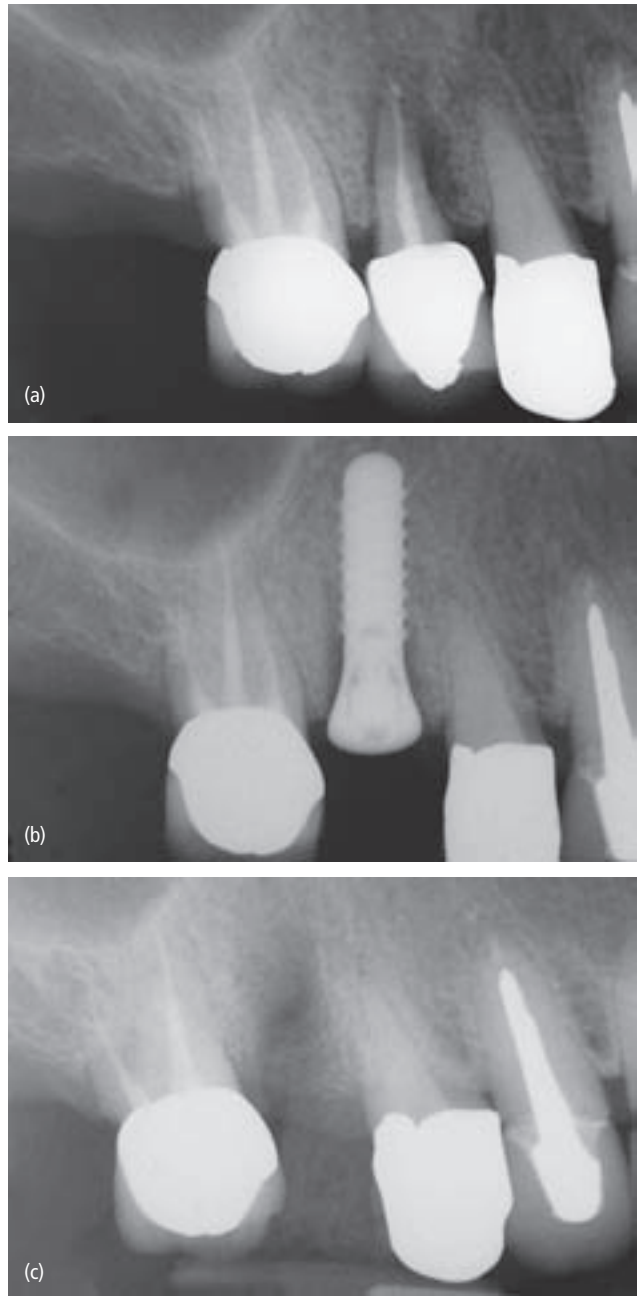


Fig. 22.22 The weakest time for healing is week 2–4 after implant insertion. (a) Initial radiograph of tooth with periapical area on tooth 4. (b) The implant was placed at the time of extraction. (c) Loss of implant occurred 4 weeks after insertion when the healing abutment was loosened.

4 mm into native bone at the apex. At week 4, the gingiva was proliferating over the cover screw (healing abutment). Therefore, it was decided to place a taller cover screw. This was an error. When the cover screw was turned to remove it, the implant rotated and came out (Fig. 22.22c). When an attempt was made to retighten the implant, it remained loose. The weakest stability for an implant is between 2 and 4 weeks postplacement during the healing phase, when the bone around the implant is

resorbing and remodeling. Others have indicated that implant stability is at its lowest between week 3 and 6 after insertion (32).

Prevention
After an implant is placed there should be no manipulation of the implant during a 12-week healing period. If an early provisional is to be placed, it should be inserted on the day of implantation or within 2–5 days of implant placement before resorption and remodeling begin.

Treatment
The implant was removed and the site was grafted. Another implant will be placed in 3 months.

Case 23: Maxillary canines often tilt distally

Etiology
The maxillary canine has an 11 degree distal tilt and curves distally 32% of the time (Fig. 22.23a) (33). This must be considered when placing an implant in the bicuspid region, because placing a vertical implant may contact and damage the adjacent tooth.

Prevention
At all times, the distal tilt of the tooth adjacent to the proposed implant site must be assessed before creating an osteotomy to avoid contacting the tooth with the drill or the implant (Fig. 22.23b). This is especially true in the maxillary first bicuspid area. For difficult cases, use of a surgical guide in conjunction with a CT scan can help locate the bicuspid implant position. The use of radiographs and direction indicators during osteotomy preparation can also help determine the need to redirect a drill.

Treatment
If the canine is dilacerated, angle the osteotomy distally away from the tooth or move the osteotomy several millimeters to the distal. Take a periapical film after initiating the osteotomy when the 2 mm twist drill depth is 5 mm to determine whether the drill needs to be reangulated. Use a guide pin in the osteotomy. To control implant angulation, use a finger from the other hand to stabilize the head of the handpiece when drilling the osteotomy to guide the handpiece.

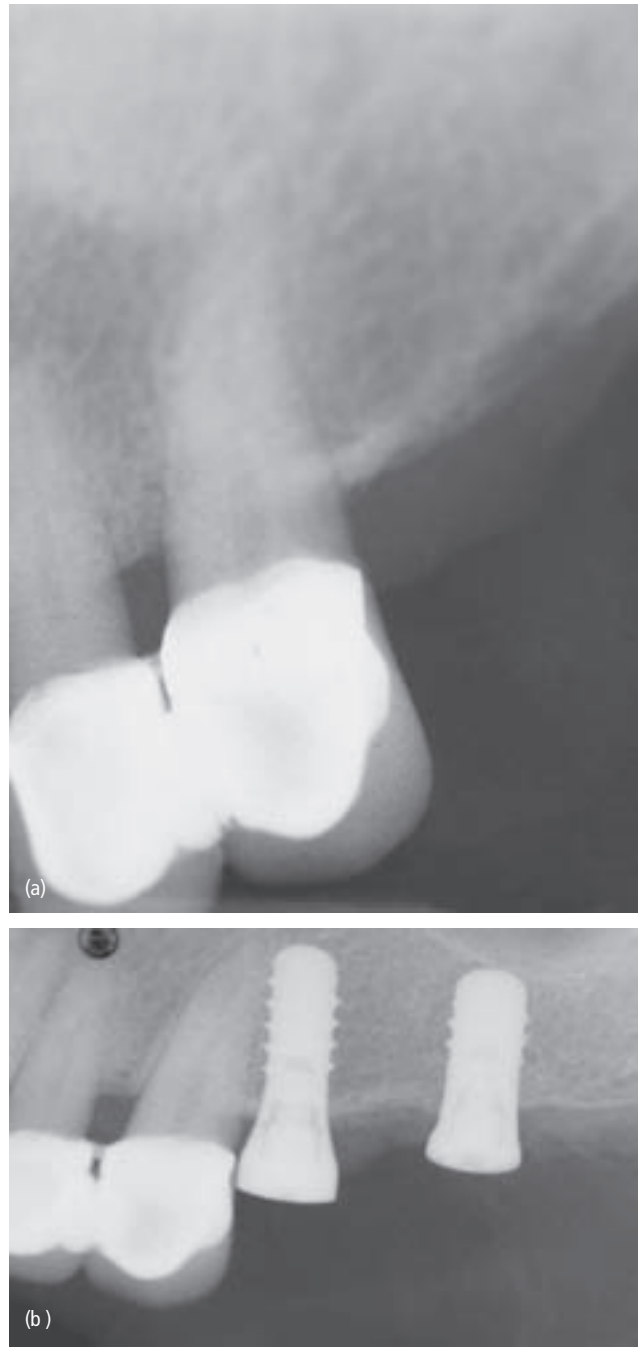


Fig. 22.23 Maxillary canines often tilt distally. (a) Maxillary canines have an 11 degree distal angulation and 32% of the time curve distally. (b) Implant at site 12 must be tipped distally or it will hit the root if placed close to the canine.

Case 24: Implant hitting the adjacent tooth

Etiology
Improper implant placement resulting in damage to the adjacent tooth (Fig. 22.24) or impingement on the tooth's blood supply can cause the tooth to become non-vital and damage the implant (34). If this happens, the injured tooth will require endodontic therapy, an apicoectomy, or removal. Furthermore, a periapical lesion that develops as a result of devitalization and encroachment may contaminate the implant and result in implant failure and removal (35).

Prevention
To avoid the above situations, the angulation of adjacent teeth and dilacerations of roots must be evaluated radio-

graphically before implant placement. Ideally at least, 1.5–2 mm of bone should be located between a tooth and an implant (36). In addition, examination of a radiograph with a guide pin at a depth of 5 mm will assist osteotomy angulation corrections.

Treatment
The implant in Fig. 22.24 should be removed and repositioned several millimeters distally to avoid losing bone between the tooth and the implant. If the tooth is damaged it should be removed; two implants would be required to replace the tooth and the damaged implant.

Case 25: Tight fit for implant placement

Etiology
A minimum edentulous distance of 7 mm is needed between teeth to enable placement of a standard implant (e.g. 4.1 mm implant with a 4.8 mm platform). This will allow 1.5 mm of bone between the teeth and the body of the implant. In Fig. 22.25(a, b) an implant was placed in a site with a 7 mm mesiodistal distance between the roots of the adjacent teeth. However, the clinical crowns of the teeth decreased the available space.

Prevention and treatment
The adjacent proximal tooth surfaces were reduced to allow placement of the implant. When the implant was inserted there still was not enough room for the lock wrench to remove the transfer mechanism. A thin diamond was used to reduce the proximal surfaces of the adjacent teeth to facilitate placement of the wrench. It is prudent to reduce the adjacent tooth surfaces before placing the implant, thereby providing space for the wrench. An alternate plan would be to use an implant with a smaller diameter or a system that uses a dedicated thin driver to remove the delivery mechanism as part of its armamentarium.

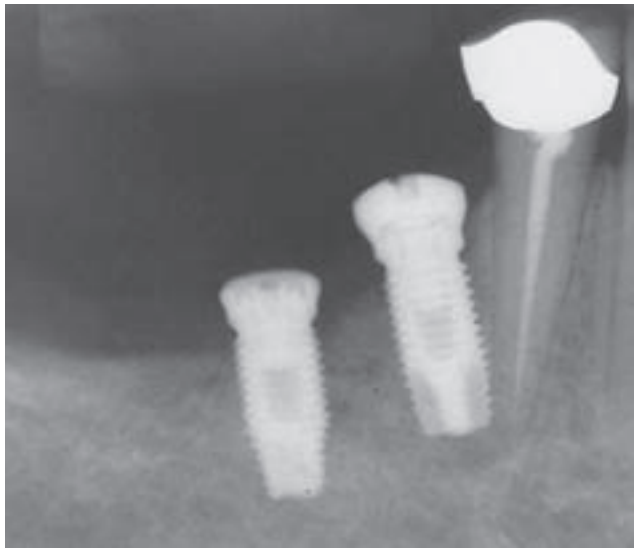


Fig. 22.24 Malpositioned implant. The implant at site 28 was placed too close to site 27 and struck the adjacent tooth.

Case 26: Immediate placement: root may be a poor guide for placement

Etiology
Roots of teeth to be extracted can be misleading with regard to positioning implants.

Prevention and treatment
Two examples are provided. The first demonstrates incorrect use of the root alveolus to guide implant placement (Fig. 22.26a, b). It resulted in the implant being placed too far distally and a small pontic needed to be constructed to fill the gap. The second demonstrates correct positioning of the implant, despite the root's previous position (Fig. 22.26c, d). An ideal wax-up and surgical guide with radiographic markers (CT scan) can help accurately determine the best implant position, which is independent of the locations of roots to be extracted. Using the roots of adjacent teeth to position implants is risky if these roots are not parallel to the teeth being extracted.

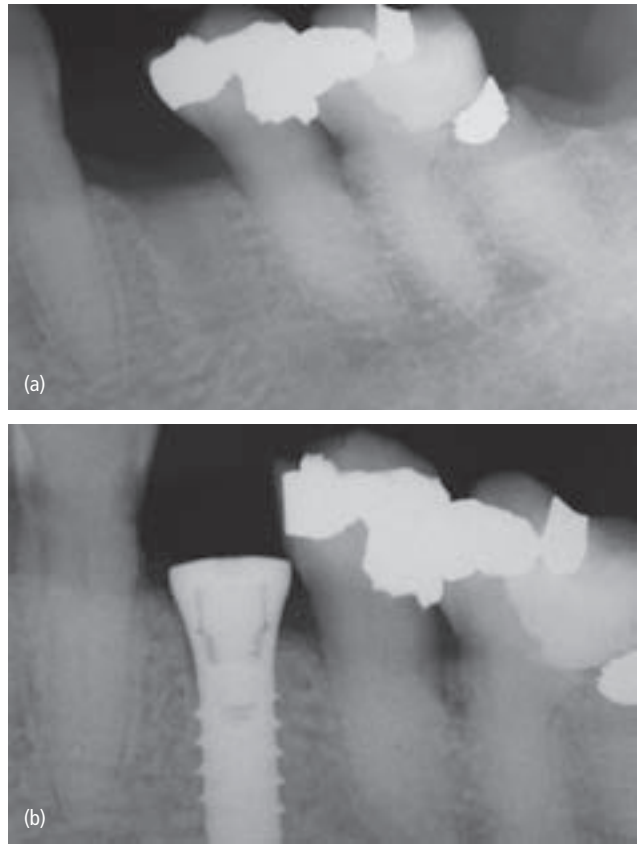


Fig. 22.25 Tight fit for implant placement. (a) Narrow mesiodistal space occlusally (6 mm), which is too narrow for a standard implant (e.g. 4.1 mm). (b) The space was widened with a bur.

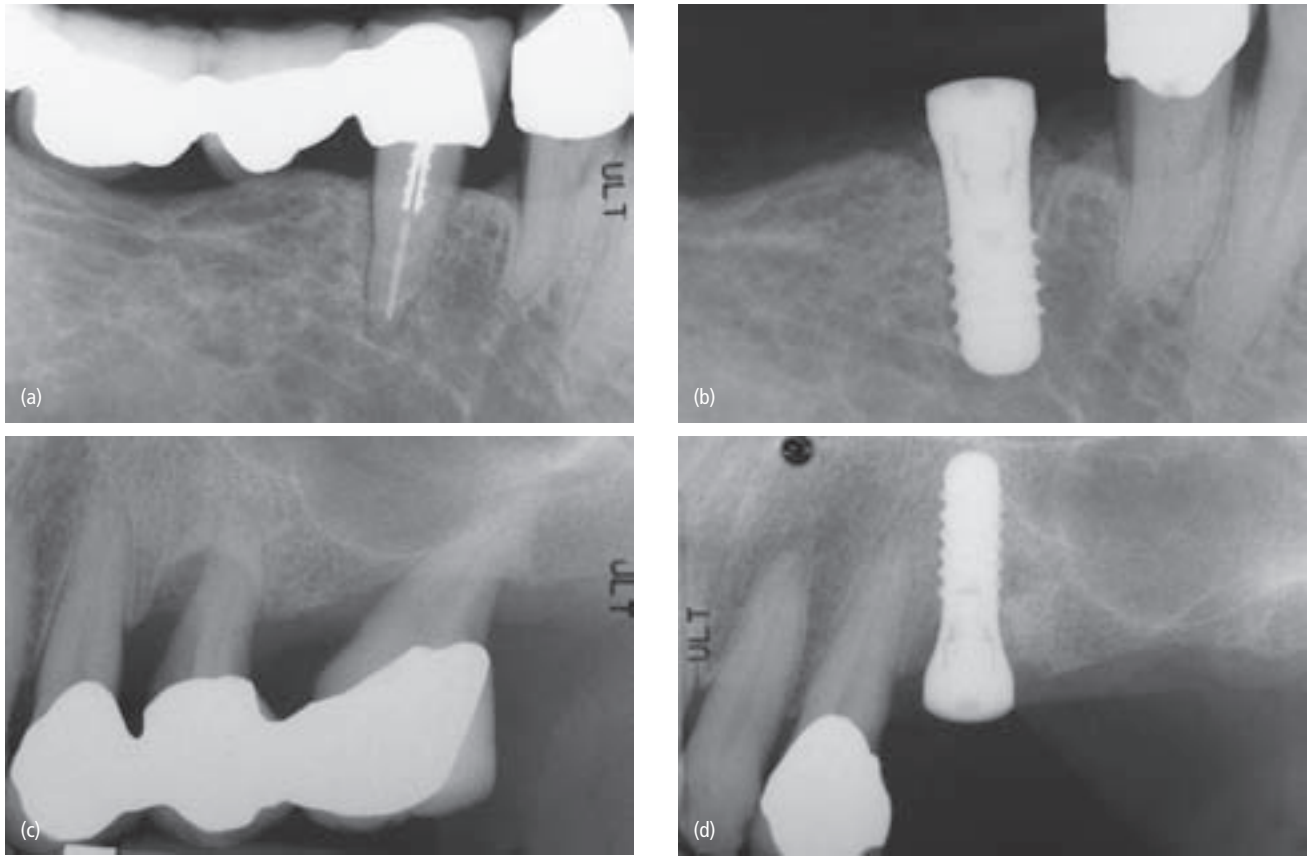


Fig. 22.26 Immediate placement: root alveoli may be poor guides for implant insertion. (a) Tooth 29, to be extracted due to caries. (b) Implant placed directly into an extraction alveolus (no. 29) resulted in the implant being too far distally. (c) Tooth 13, to be extracted. (d) Tooth 13 was too far distal to the adjacent tooth. A Lindemann bur was used to move the site of the osteotomy horizontally closer to the mesial to ensure a 1.5–2 mm space between the tooth and the implant.

Case 27: Inadequate bone height for an implant found upon flap elevation: switch to simultaneous placement with lateral window sinus lift

Etiology

Radiographically, site no. 3 appeared to have enough bone height to perform an osteotome sinus lift and implant placement (Fig. 22.27a). However, upon flap elevation, it was determined that the bone presented too much of a buccal undercut for proper implant positioning (Fig. 22.27b).

Prevention

A CT scan would have provided definitive information before the surgery. In addition, the clinician's skill and knowledge pertaining to various surgical procedures allows flexibility in changing procedures as the condition dictates.

Treatment

There was insufficient bone height available to do an osteotome sinus lift. Thus, a one-tooth lateral window sinus lift was performed (Fig. 22.27b). Bone was placed in the sinus (Fig. 22.27c), a barrier positioned, and an implant inserted. Subsequently, the case was restored (Fig. 22.27d).

Postoperative problems

Case 28: Ecchymosis

Etiology

The presence of an ecchymosis indicates that there was damage to blood vessels within the skin or mucous membranes. These patches are non-elevated, rounded, or irregular, and are initially a red–blue or purplish color. Goodacre *et al.* (5) reported that subsequent to implant placement the incidence of ecchymosis was around 24%. The location of the ecchymosis can be influenced by gravity. It may be perceptible only at the site of injury, or it could extend to the inferior border of the mandible or onto the chest (Fig. 22.28). This latter result does not denote that tissues were mismanaged, rather it indicates that there was bleeding under the flap and blood moved along the fascial planes.

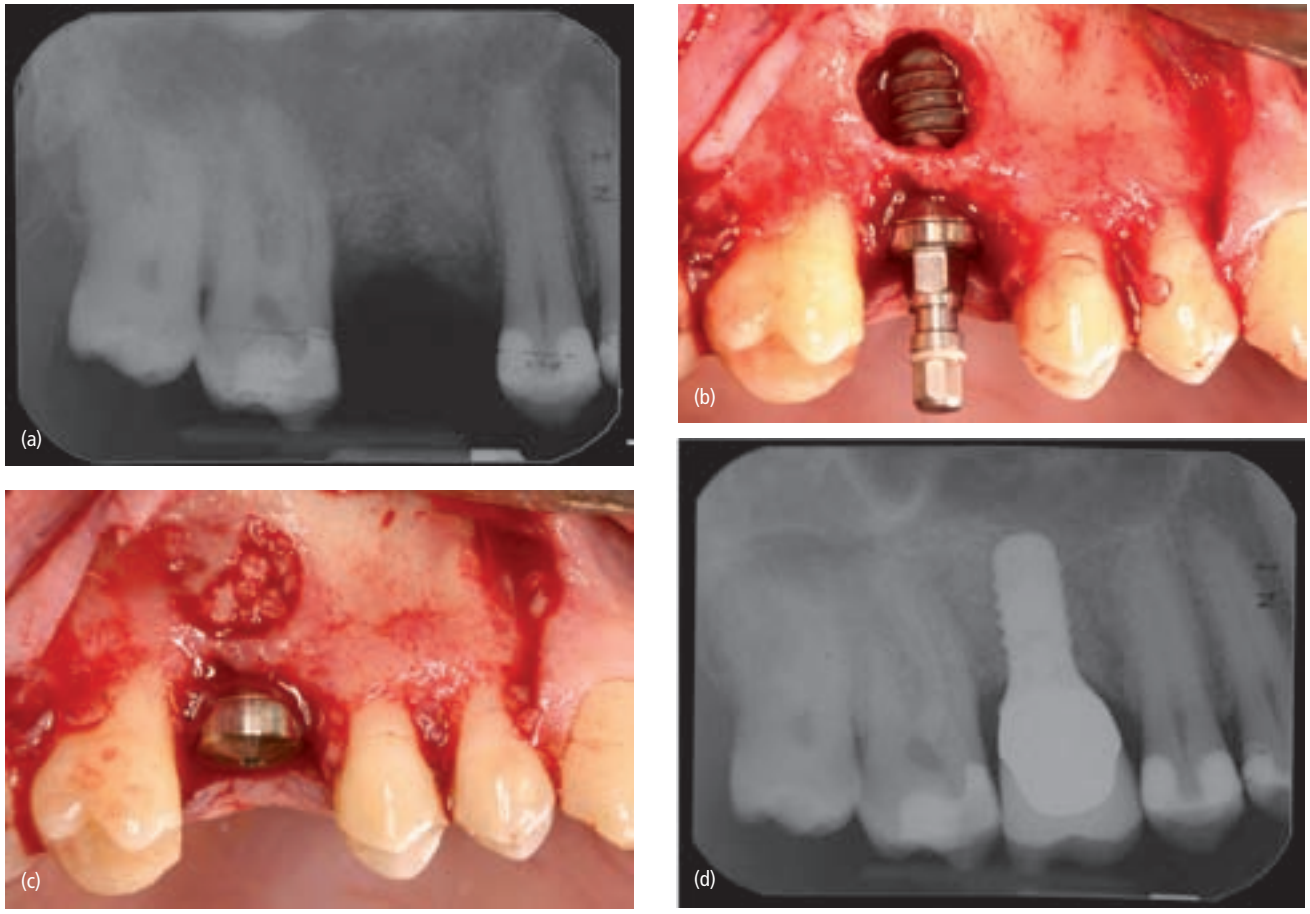


Fig. 22.27 Grafted area failed to calcify: switch to immediate placement with lateral window sinus lift. (a) Initial radiograph. There appeared to be enough bone to carry out a sinus floor elevation. (b) Flap elevation revealed that the crestal bone sloped buccally and there was not enough bone to perform an osteotome sinus floor elevation. (c) A lateral window sinus lift was developed, and bone was placed into window and covered with a barrier. (d) The implant at site 3 was restored 6 months later.

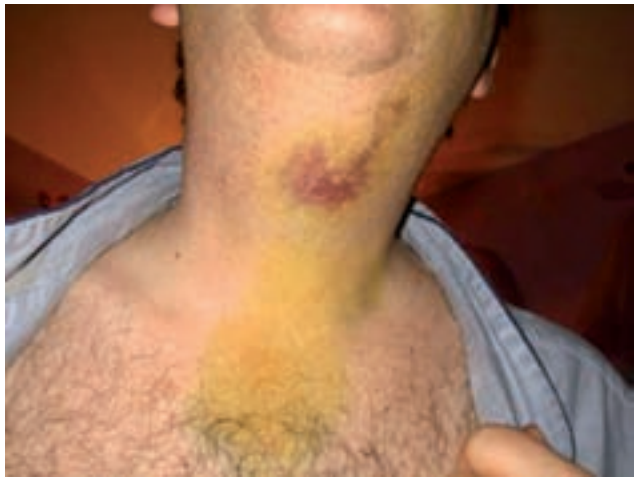


Fig. 22.28 Ecchymosis onto the chest occurred after a sinus lift. Blood transcended along the facial planes.

Prevention

Ecchymosis development may be unavoidable. However, gentle handling of the tissue reduces its occurrence. Before a patient is dismissed, visual inspection should reveal no bleeding and pressure should be applied to mediate clot formation and eliminate dead space with subsequent oozing. Furthermore, the patient should be advised to stop all anticoagulants (in conjunction with consultation with the physician) 4–7 days before surgery.

Treatment

The presence of an ecchymosis does not require treatment. Oral and printed postoperative directions should notify and assure a patient that this sequela is a possibility and does not require treatment.

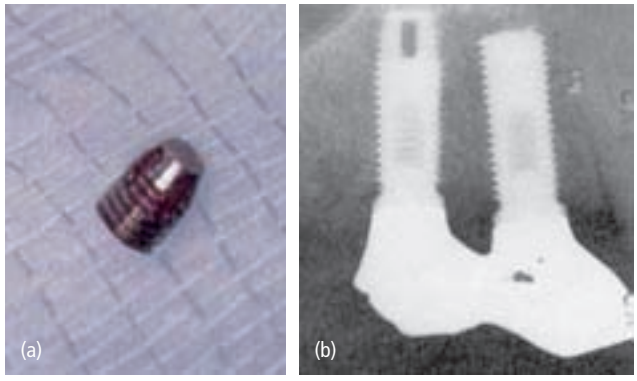


Fig. 22.29 Symptomatic periapical lesion around an implant. (a) The apex of the implant was removed. (b) Healed apex of no. 4. (Courtesy of Dr Tarnow.)

Case 29: Symptomatic periapical lesion around an implant

Etiology
There are several possible reasons for development of periapical pathosis around an implant: bacterial contamination at the time of insertion, overheating of bone during osteotomy development resulting in necrosis, devitalization of an adjacent tooth, and residual pathosis in the bone. In one study, approximately 1% of implants placed during a 5-year period developed periapical pathosis, also referred to as a retrograde peri-implantitis (37). These lesions can be classified as active (symptomatic) or inactive.

Prevention
Attention to detail when developing an osteotomy avoids damaging adjacent teeth and the use of copious irrigation with saline circumvents overheating the bone. In this regard, the clinician should use only sharp burs and follow the manufacturer's recommendations with respect to cutting speeds, which may vary from one implant system to another.

Treatment
Inactive lesions require no treatment when the radiolucency remains unchanged (37). If the site is symptomatic, the patient may appear with pain, tenderness, swelling, or a fistulous tract. Periapical defects around implants that are symptomatic require surgical débridement and antibiotic treatment (38). If the apex cannot be completely débrided, the implant should be resected (Fig. 22.29a, b) and a bone graft may assist in preventing collapse of a bioabsorbable barrier. If pain or the lesion persists, the entire implant should be removed.

Case 30: Infection after placement of dental implants

Etiology
The patient was recently treated with four quadrants of periodontal surgery and healed uneventfully. She had hepatitis C and was asymptomatic. This type of infection can cause liver inflammation (hepatitis) (39). There is no contraindication to placing implants in patients with hepatitis C. Figure 22.30(a–d) demonstrates that after successful periodontal surgery when implants were placed, within 4 weeks implants failed at both sites 19 and 30. The patient had been placed on clindamycin for 1 week after surgery. The aerobic–anaerobic status of common periodontal and implant pathogens is listed below:

- Anaerobes: *Porphyromonas gingivalis*, *Prevotella intermedia*, *Tannerella forsythensis*, *Peptostreptococcus micros*, *Spirochetes*, *Fusobacterium nucleatum*
- Facultative: *Eikenella corrodens*, *Campylobacter rectus*
- Microaerophilic: *Aggregatibacter actinomycetemcomitans*.

It should be noted that the spectrum of activity for clindamycin and metronidazole is obligate anaerobes. They do not kill other bacteria. Therefore, it is apparent that organisms other than anaerobes induced an infection resulting in loss of both implants.

Prevention
If the patient decides to be retreated a culture should be taken to determine which organisms are present and appropriate antibiotic(s) should be used to reduce the bacterial challenge to implant survival.

Treatment
Both implants were removed and the patient decided not to proceed with additional therapy.

Sinus issues

Case 31: Sinus wall fenestration

Etiology
A 55-year-old Caucasian female required a sinus lift in the right maxilla to facilitate implant placement. Review of her CT scan (Fig. 22.31) indicated that a portion of the buccal plate was missing adjacent to the right maxillary sinus. She reported that several years ago, a benign cyst was removed from this region. When the site was previously treated, the flap was replaced over the fenestration and this resulted in the submucosa of the flap and the Schneiderian membrane fusing together during healing.

Prevention
Careful inspection of the CT scan revealed a fenestration of buccal bone, which dictated altering the flap design and elevation technique to avoid sinus membrane perforation.

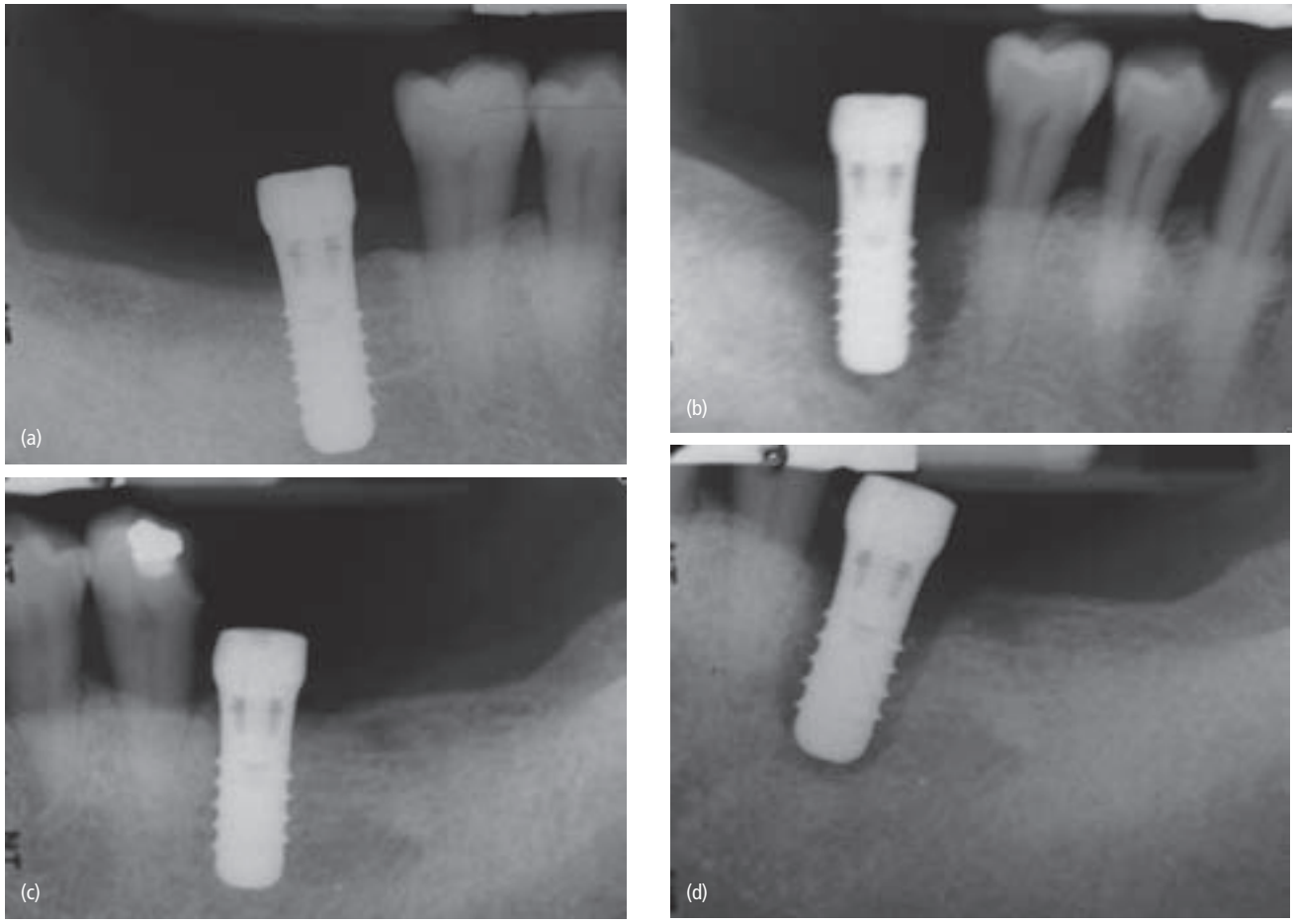


Fig. 22.30 Hepatitis C patient 4 weeks after implantation: two sites. (a) Site 30, initial placement of implant. (b) Failed implant, 4 weeks after implantation. (c) Site 19, initial placement of implant. (d) Failed implant, 4 weeks after implantation.

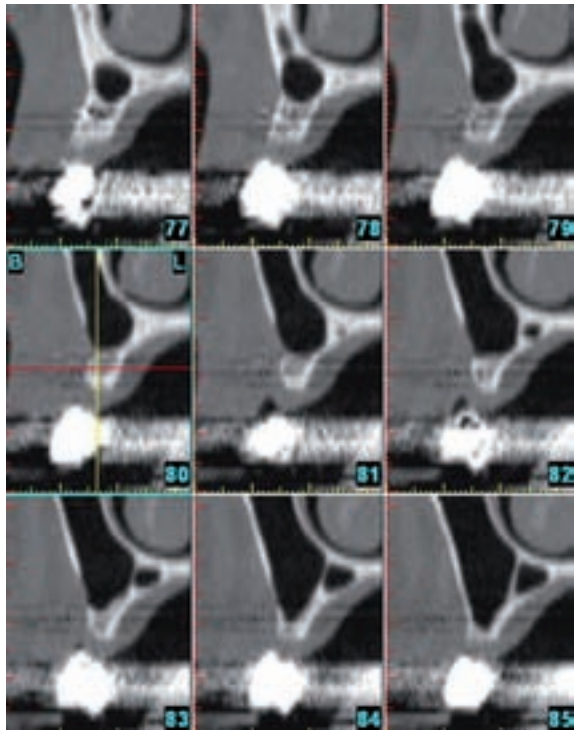


Fig. 22.31 Sections 79–84 of the CT scan reveal a fenestration of bone in the lateral wall of the sinus.

Treatment

Management of the buccal fenestration of bone dictated cautious flap design and reflection. A periosteal elevator was used to release the gingiva to the mucogingival junction. The elevator was then used with wet non-woven gauze to reflect the mucosa. When the fenestration was located, the flap was held with a toothed Adson forcep, and a scalpel was used to split the submucosa, leaving several millimeters of connective tissue over the fenestration. This was done to avoid pulling the Schneiderian membrane out of the sinus and tearing it. Subsequently, the lateral window was expanded and the soft tissue over the window and the Schneiderian membrane were elevated together, because it is impossible to separate precisely the Schneiderian membrane from the underside of the flap. The remainder of the sinus lift procedure was completed without any untoward results.

Case 32: Tissue from extraction site adheres to the Schneiderian membrane

Etiology

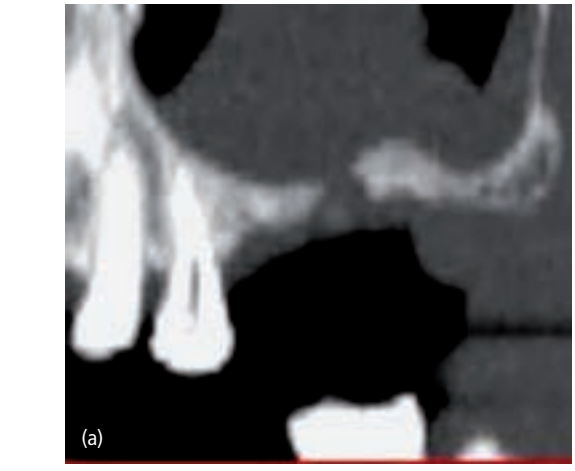
In this patient, several extractions were done 3 months before the sinus lift procedure. After the flap was elevated and the lateral window was developed, the Schneiderian membrane was released. However, there were adhesions on the inferior wall of the window that could not be released with instrumentation in the sinus (Fig. 22.32a).

Prevention

Careful inspection of the CT scan revealed a fenestration in the floor of the sinus, which dictated an alternate flap design lingual to the alveolar ridge to avoid sinus membrane perforation.

Treatment

The flap at the crest of the bone required elevation on the palatal aspect to reveal a fenestration in the bone that did not heal after the teeth were extracted (Fig. 22.32b). Within this fenestration there was connective tissue, which was fused to the Schneiderian membrane. The soft tissue was elevated and the membrane became detached from the inferior wall. The sinus lift was completed without additional sequelae.



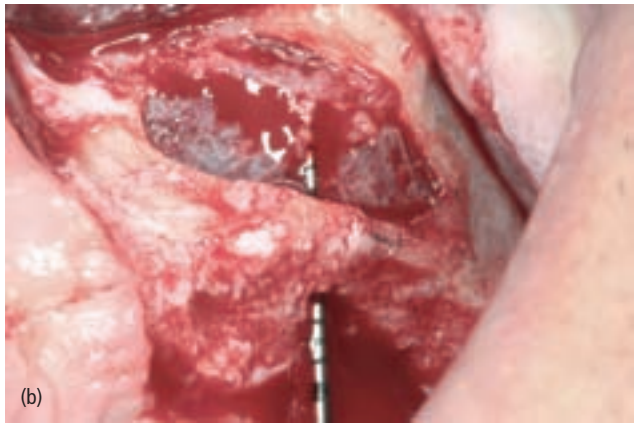


Fig. 22.32 Tissue from extraction site adheres to the Schneiderian membrane. (a) CT scan reveals fenestration in the inferior wall of the sinus. (b) Periodontal probe penetrating through the floor of the sinus after the tissue was released and pressed into the sinus.

Case 33: Perforation of the Schneiderian membrane during osteotomy preparation

Etiology

When there is a limited amount of bone subantrally to place an implant, an osteotome sinus elevation can be performed as an alternative to creating a lateral window. Drill 1 mm short of the sinus floor with the narrowest twist drill (verify this with a radiograph). Continue from the narrowest to the widest twist drill that usually would be used before placing an implant. Then, add bone to the osteotomy and infracture the cortical floor of the sinus with the osteotome (tap it with a mallet). Before infracturing the subantral bone with the osteotome, set the depth stop on the osteotome so that it will engage the osseous crest when the osteotome tip is 1 mm short of the subantral floor. This will ensure that the instrument will not penetrate into the sinus. However, in this case there was inadvertent perforation of the Schneiderian membrane with the first twist drill.

Prevention

Drill 1–2 mm short of the subantral floor to account for radiographic and clinician error. Take X-rays as needed to assess the position of the drill tip as it progresses closer to the floor of the sinus. Drills stops should be used. The sinus floor and membrane should be elevated by the graft used in the procedure with pressure from the osteotome always inserted 1 mm short of the sinus floor.

Treatment

When a Schneiderian membrane perforation occurs during an osteotome technique, there are three options: abort the procedure, continue with the sinus elevation, or resort to a conventional lateral window sinus lift. If the membrane is perforated with the first twist drill (e.g. 2.2 mm) it is possible to complete the procedure (Fig. 22.33a–c). Drill the second and third twist drills (e.g. 2.8 mm and 3.5 mm) 1 mm short of the perforation and then infracture the subantral floor. Add some bone through the osteotomy and determine radiographically whether a dome (contained radiopacity) can be achieved. If the graft material is contained owing to the membrane collapsing upon itself, additional material can be added to attain the desired height of bone and the procedure can be completed. It is important that the implant attains good primary stability. However, if the graft material is scattered, the procedure must be aborted or a lateral window performed to complete the elevation and sinus augmentation.

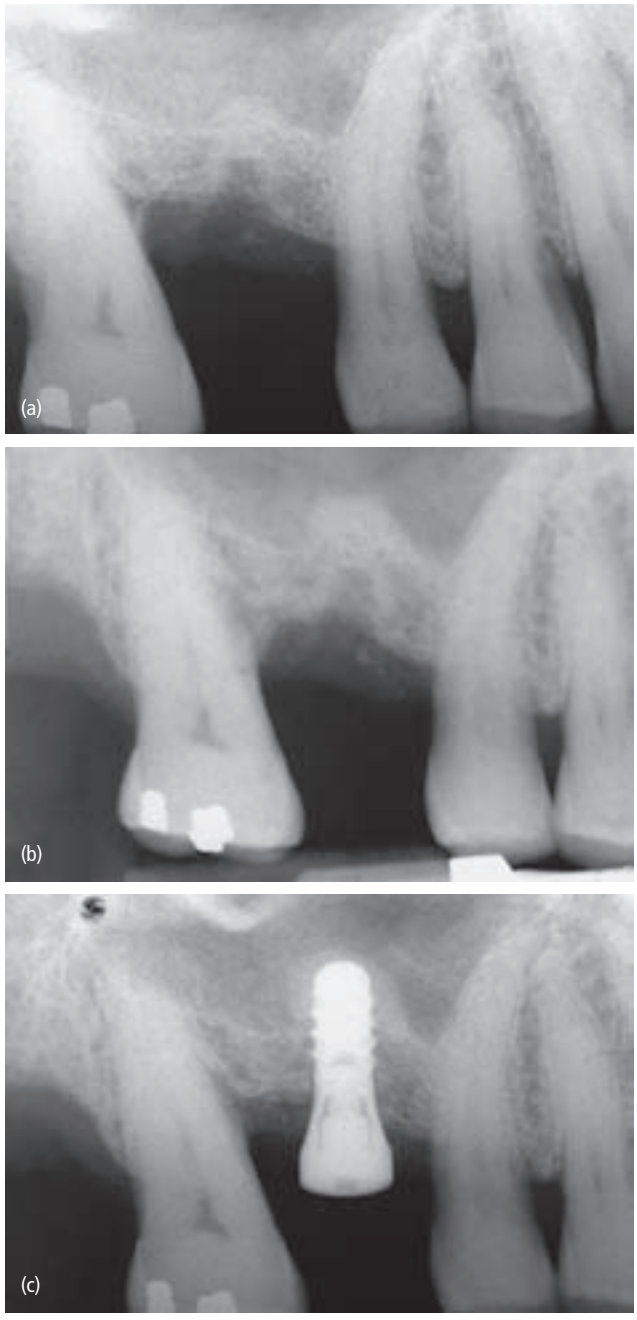


Fig. 22.33 Perforation of the Schneiderian membrane: salvation of an osteotome sinus elevation. (a) Despite initial perforation into the sinus with the first twist drill, the initial puff of bone attained after infracturing the subantral floor after the third drill indicated that the procedure could be completed. (b) Additional bone was added via the osteotomy. (c) Implant successfully placed.

Case 34: Implant in the sinus

Etiology

The patient in Fig. 22.34 presented for a consultation after detecting that one of her implants was not present. A CT scan and a Panorex revealed that the implant was displaced into her left maxillary right sinus (Fig. 22.34).

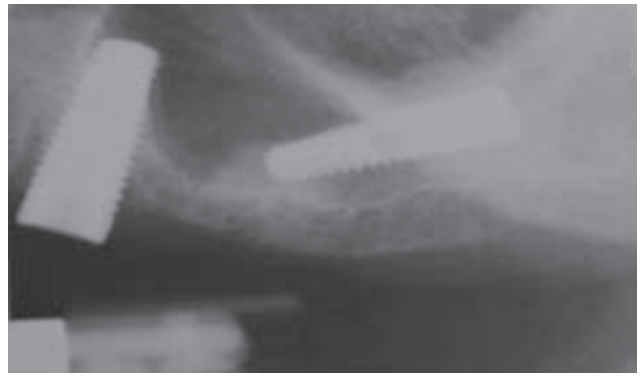


Fig. 22.34 An implant became displaced into the maxillary right sinus after it was inserted. There was a dearth of native bone to provide primary stability. It needed to be removed via a lateral window.

There are several scenarios that can account for this mishap. An implant can become dislodged into the sinus during implant insertion if it is placed into soft bone and there is inadequate subantral cortical bone to provide adequate primary stability. It can also occur subsequent to implant placement as the bone resorbs around the implant. In this case, implant migration occurred after placement.

Prevention

If there is insufficient subantral bone to retain an implant, consideration should be given to an augmentation procedure via a lateral window sinus lift or an osteotome sinus elevation. These procedures can be performed before implant placement or simultaneously with implant insertion if there is adequate bone to provide primary stability. If a lateral window approach is used the graft material should be allowed to mineralize 6–9 months before implant insertion.

Treatment

During implant placement or after its insertion, if an implant is inadvertently displaced into the sinus cavity, it should be removed as soon as possible to avoid developing sinusitis. A radiographic assessment should be carried out to determine the location of the implant. To provide access to the implant, a lateral window into the sinus (Caldwell-Luc procedure) must be created to locate and remove the implant. If the implant has fallen into a recess within the sinus the suction tip can be used to remove the implant (40, 41).

Fractured mandible

Case 35: Mandibular jaw fracture of an atrophic jaw

Etiology

An unusual, but potentially serious complication of implant insertion or removal is fracture of an atrophic

mandible. Figure 22.35 depicts a fracture of the mandibular jaw that occurred subsequent to removal of a failed implant at site 26. The patient initially presented with an atrophied mandible and desired insertion of dental implants. Four implants were submerged at sites corresponding to the mandibular laterals and canines. At that point in time, a Panorex did not reveal a mandibular fracture. Healing was initially uneventful; however, after 3 months the patient experienced pain and swelling around the mandibular right lateral incisor. Second stage surgery was initiated and revealed that the implant at no. 26 was mobile; it was removed. A radiograph revealed a mandibular fracture at site 26.

Prevention

Maintenance of the structural integrity of the atrophic mandible can help avoid a fractured jaw. In this regard, the inferior border of the mandible is often used for implant stability, but it should not be disrupted, since it could weaken the mandible. In addition, wide implants may further weaken an atrophic mandible. Therefore, before their placement it needs to be verified that the mandible is sufficiently thick to accommodate an implant without sacrificing too much bone. Pertinently, Park and Wang (42) suggested that there is increased vulnerability to fracture if there is less than 7 mm of bone height and 6 mm of bone width.

Treatment

An atrophic mandible with an implant may fracture under normal conditions. When this happens, Laskin (43) indicated that the amount of displacement will be a critical factor in choosing the best therapy. If the fractured bone demonstrates little mobility or displacement, the implant can be retained (43). When there is no radiographic proof of dislocation, but some mobility, the fracture can be reduced in a closed manner (44). For the patient in Fig. 22.35, handling of the mandible site did not result in abnormal movement at the fracture site. Therefore, she was advised to use a soft/liquid diet for 3 months and was prescribed clindamycin. In addition, an abutment level impression was obtained and a Dolder bar was fabricated. It was attached to the remaining implants with occlusal screws. Immobilization of the fragmented mandible resulted in complete healing within 4 months.

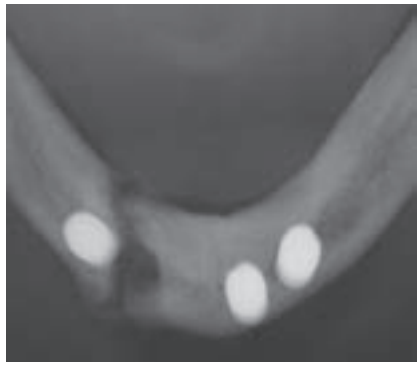


Fig. 22.35 The atrophied mandible became fractured after removal of a failed implant at site 26. (Reprinted with permission from *J Periodontol* (19).)

Take-home hints

- Successful implant dentistry is based on careful treatment planning and attention to detail when executing therapy.
- Known biologic principles that have been tested on the anvil of time need to be respected.
- If feasible, keep the treatment plan uncomplicated.
- Accomplish one small miracle at a time.
- Always consider the restorative outcome.
- Be prepared to alter the treatment plan.
- Share your knowledge with others.
- Preserve a standard of excellence.
- Know what to do if a complication occurs.
- Care for patients the way you would like to be treated.

References

1. Littner MM, Kaffe I, Tamse A, Dicapua P. Relationship between the apices of the lower molars and mandibular canal – a radiographic study. *Oral Surg Oral Med Oral Pathol* 1986; **62**: 595–602.
2. Denio D, Torabinejad M, Bakland LK. Anatomical relationship of the mandibular canal to its surrounding structures in mature mandibles. *J Endod* 1992; **18**: 161–5.
3. Sonick M, Abrahams J, Faiella RA. A comparison of the accuracy of periapical, panoramic, and computerized tomographic radiographs in locating the mandibular canal. *Int J Oral Maxillofac Implants* 1994; **9**: 455–60.
4. Powell LV. Caries prediction: a review of the literature. *Community Dent Oral Epidemiol* 1998; **266**: 361–71.
5. Goodacre CJ, Bernal G, Rungcharassaeng K, Kan JY. Clinical complications with implants and implant prostheses. *J Prosthet Dent* 2003; **90**: 121–32.
6. Blanco J, Nuñez V, Aracil L, Muñoz F, Ramos I. Ridge alterations following immediate implant placement in the dog: flap versus flapless surgery. *J Clin Periodontol* 2008; **35**: 640–8.
7. Fickl S, Zuhr O, Wachtel H, Stappert CF, Stein JM, Hürzeler MB. Dimensional changes of the alveolar ridge contour after different socket preservation techniques. *J Clin Periodontol* 2008; **35**: 906–13.
8. Cardaropoli G, Araújo M, Hayacibara R, Sukekava F, Lindhe J. Healing of extraction sockets and surgically produced – augmented and non-augmented – defects in the alveolar ridge. An experimental study in the dog. *J Clin Periodontol* 2005; **32**: 435–40.

9. Choquet V, Hermans M, Adriaenssens P, Daelemans P, Tarnow DP, Malevez C. Clinical and radiographic evaluation of the papilla level adjacent to single-tooth dental implants. A retrospective study in the maxillary anterior region. *J Periodontol* 2001; **72**: 1364–71.
10. Carmagnola D, Adriaens P, Berglundh T. Healing of human extraction sockets filled with Bio-Oss. *Clin Oral Implants Res* 2003; **14**: 137–43.
11. Mraiwa N, Jacobs R, Van Cleynenbreugel J, Sanderink G, Schutyser F, Suetens P, *et al.* The nasopalatine canal revisited using 2D and 3D CT imaging. *Dentomaxillofac Radiol* 2004; **33**: 396–402.
12. Artzi Z, Nemcovsky CE, Bitlitum I, Segal P. Displacement of the incisive foramen in conjunction with implant placement in the anterior maxilla without jeopardizing vitality of nasopalatine nerve and vessels: a novel surgical approach. *Clin Oral Implants Res* 2000; **11**: 505–10.
13. Rosenquist JB, Nystrom E. Occlusion of the incisal canal with bone chips. A procedure to facilitate insertion of implants in the anterior maxilla. *Int J Oral Maxillofac Surg* 1992; **21**: 210–11.
14. Greenstein G, Tarnow D. The mental foramen and nerve: clinical and anatomical factors related to dental implant placement: a literature review. *J Periodontology* 2006; **77**: 1933–43.
15. Solar P, Ulm C, Frey G, Matejka M. A classification of the intraosseous paths of the mental nerve. *Int J Oral Maxillofac Implants* 1994; **9**: 339–44.
16. Hebel KS, Gajjar R. Anatomic basis for implant selection and positioning. In: Babbush CA, ed. *Dental implants. The art and science*. Philadelphia, PA: Saunders, 2001: 85–106.
17. Casap N, Zeltser C, Wexler A, Tarazi E, Zeltser R. Immediate placement of dental implants into débrided infected dentoalveolar sockets. *J Oral Maxillofac Surg* 2007; **65**: 384–92.
18. Goaslind GD, Robertson PB, Mahan CJ, Morrison WW, Olson JV. Thickness of facial gingiva. *J Periodontol* 1977; **48**: 768–71.
19. Greenstein G, Cavallaro J, Romanos G, Tarnow D. Clinical recommendations for avoiding and managing some surgical complications associated with implant dentistry: a review. *J Periodontol* 2008; **79**: 1317–29.
20. Schropp L, Wenzel A, Kostopoulos L, Karring T. Bone healing and soft tissue contour changes following single-tooth extraction: a clinical and radiographic 12-month prospective study. *Int J Periodontics Restorative Dent* 2003; **23**: 313–23.
21. Lekovic V, Kenney EB, Weinlaender M, Han T, Klokkevold P, *et al.* A bone regenerative approach to alveolar ridge maintenance following tooth extraction. Report of 10 cases. *J Periodontol* 1997; **68**: 563–70.
22. Block MS. *Color atlas of dental implant surgery*. Philadelphia, PA: WB Saunders Co., 2001: 9.
23. Misch CE, Crawford EA. Predictable mandibular nerve location – a clinical zone of safety. *Int J Oral Implantol* 1990; **7**: 37–40.
24. Day RH. Diagnosis and treatment of trigeminal nerve injuries. *J Calif Dent Assoc* 1994; **22**: 48–54.
25. Meyer RA. Nerve injuries associated with third molar removal. *Oral Maxillofac Surg Knowledge Update* 1995; **1**: 35–47.
26. Kraut RA, Chahal O. Management of patients with trigeminal nerve injuries after mandibular implant placement. *J Am Dent Assoc* 2002; **133**: 1351–4.
27. Worthington P. Injury to the inferior alveolar nerve during implant placement: a formula for protection of the patient and clinician. *Int J Oral Maxillofac Implants* 2004; **19**: 731–4.
28. Robinson M, Slavkin HC. Dental amputation neuromas. *J Am Dent Assoc* 196; **70**: 662–675.
29. Lee HT. Amputation neuroma of the maxilla. *Dent J Malaysia Singapore* 1971; **11**: 17–19.
30. Hegedus F, Diecidue RJ. Trigeminal nerve injuries after mandibular implant placement – practical knowledge for clinicians. *Int J Oral Maxillofac Implants* 2006; **21**: 111–16.
31. Tupac RG. When is an implant ready for a tooth? *J Calif Dent Assoc* 2003; **31**: 911–15.
32. Ersanli S, Karabuda C, Beck F, Leblebicioglu B. Resonance frequency analysis of one-stage dental implant stability during the osseointegration period. *J Periodontol* 2005; **76**: 1066–71.
33. Misch CE. Root form surgery in the edentulous mandible: stage I implant insertion. In: Misch CE, ed. *Implant dentistry*, 2nd edn. St Louis, MO: CV Mosby, 1999: 347–70.
34. Sussman HI. Tooth devitalization via implant placement: a case report. *Periodont Clin Investig* 1998; **20**: 22–4.
35. Tseng CC, Chen YH, Pang IC, Weber HP. Peri-implant pathology caused by periapical lesion of an adjacent natural tooth: a case report. *Int J Oral Maxillofac Implants* 2005; **20**: 632–5.
36. Buser D, Martin W, Belser UC. Optimizing esthetics for implant restorations in the anterior maxilla: anatomic and surgical considerations. *Int J Oral Maxillofac Implants* 2004; **19** (Suppl): 43–61.
37. Quirynen M, Gijbels F, Jacobs R. An infected jawbone site compromising successful osseointegration. *Periodontol 2000* 2003; **33**: 129–44.
38 Jalbout ZN, Tarnow DP. The implant periapical lesion: four case reports and review of the literature. *Pract Proced Aesthet Dent* 2001; **13**: 107–12.
39. de Bruijne J, Buster EH, Gelderblom HC, Brouwer JT, de Knegt RJ, van Erpecum KJ, *et al.* Netherlands Association of Gastroenterologists and Hepatologists. Treatment of chronic hepatitis C virus infection – Dutch national guidelines. *Neth J Med* 2008; **66**: 311–22.
40. Uckan S, Buchbinder D. Sinus lift approach for the retrieval of root fragments from the maxillary sinus. *Int J Oral Maxillofac Surg* 2003; **32**: 87–90.
41. Matheny KE, Duncavage JA. Contemporary indications for the Caldwell-Luc procedure. *Curr Opin Otolaryngol Head Neck Surg* 2003; **11**: 23–6.
42. Park SH, Wang HL. Implant reversible complications: classification and treatments. *Implant Dent* 2005; **14**: 211–20.
43. Laskin DM. Nonsurgical management of bilateral mandibular fractures associated with dental implants: report of a case. *Int J Oral Maxillofac Implants* 2003; **18**: 739–44.
44. Raghoebar GM, Stellingsma K, Batenburg RHK, Vissink A. Etiology and management of mandibular fractures associated with endosteal implants in the atrophic mandible. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2000; **89**: 553–8.

Chapter 23

Implant complications related to maintenance therapy

Robert N. Eskow DMD, MScD and Valerie Sternberg Smith RDH, BS

Introduction

The maintenance phase of implant dentistry encompasses the preventive care necessary to preserve the health and integrity of the soft and hard tissues surrounding the implant and the procedures required to sustain the function and esthetics of the restoration. This is the longest phase of involvement for the patient treated with implant dentistry, and has the greatest impact on achieving the long-term prognosis of an implant-supported restoration. The ultimate success of preventive care begins in the diagnostic and treatment planning phases. Appreciation of the endogenous factors – the flora, forces generated by occlusal function and habits, systemic influences, bone and soft-tissue anatomy – as well as implant characteristics, implant placement, and restorative design will affect the maintenance required and the resultant prognosis.

The complications encountered during the preventive phase are most commonly expressed as changes in the peri-implant bone and soft tissue or loss of integrity of the restorative components (1) (Table 23.1). Understanding the etiology and instituting the appropriate preventive and treatment regimens is essential to successfully managing the complication with which a patient presents. The preventive protocol used to preserve the health of the peri-implant tissues consists of two phases. The first, the assessment phase, requires that the clinician differentiate between the presence of health and disease. In addition, etiologic factors or risk factors that can be responsible for deviations from health should be identified (Table 23.2). The second aspect of this regimen is the hygiene phase. This consists of training and directing the patient to control the potential etiologic factors that can result in peri-implant disease or damage to the restoration. Included in this phase is débridement, by the therapist at the appropriate intervals.

The preventive care visit begins with the assessment phase and as with all other visits includes a review of the patient's medical history. The assessment phase comprises:

- a review of the medical history
- a review of the dental history
- reports of pain or discomfort
- an extraoral and intraoral examination
- calculation of the plaque score
- checks for calculus presence and location
- peri-implant soft-tissue examination
- examination of the restoration
  - assessment of occlusal wear
  - checking that connections are intact
  - checks for fracture or chipping
- radiographic examination
  - assessment of crestal bone levels and morphology
  - assessment of bone-to-implant interface
  - checking that connections are intact.

Changes in the patient's systemic status might be known and reported by the patient. Frequently, vigilance on the part of the clinician based on changes in clinical presentation of any of the items listed above may detect an undiagnosed or unreported systemic change. It has recently been reported that 80% of adults take at least one medication (2). The medications commonly used by the population treated with implant dentistry can contribute to complications associated with long-term preventive care. Entities influenced by medications include saliva, soft tissue, bone, and occlusion. For example, something as routine as a review of the indication for recently performed dentistry may reveal changes in the patient's medical status. Fundamentally, the patient who received osseointegrated implants may be a very different individual from the one for whom we are trying to sustain osseointegration.

Inflammatory peri-implant disease

Inflammatory disease in the peri-implant tissues limited to the soft tissue is termed mucositis (Fig. 23.1a, b). The extension of inflammation into the bone surrounding the implant with resultant bone loss defines peri-implantitis (3) (Fig. 23.2a, b) (see Chapter 7). Unabated bone loss can result in the complete loss of osseointegration (4).

Table 23.1 Complications encountered during the preventive phase of treatment

Complication	Clinical presentation	Etiology
Inflammatory peri-implant disease		
Mucositis	Bleeding on probing/palpation	Plaque
	Suppuration on probing/palpation	Cement
	Changes in color, form, texture	Loose restorative components
Peri-implantitis	Bleeding on probing/palpation	Plaque
	Suppuration on probing/palpation	Cement
	Change in color, form, texture	Loose restorative components
	Loss of bone as detected on X-rays compared to previous X-rays	Smoking
		Alcohol consumption
		Systemic disease
		Occlusal disease
Peri-implant mucosal hyperplasia		
	Tissue overgrowth	Overdenture
		Ill-fitting prosthesis
		Medications
Loss of stability of the restorative components		
	Peri-implant inflammation	
	Loose prosthesis	Loose screw(s)
	Bleeding/suppuration from the peri-implant crevice	Fractured screw(s)
	Bone loss	Fractured implant fixture(s)
		Loss of cement adhesion
		Non-integrated implant
Non-maintainable environment		
	Bleeding/suppuration from peri-implant crevice	Implant too close to adjacent implant
	Change in peri-implant mucosa color/form/texture	Implant too close to adjacent tooth
	Non-adherent tissue around implant	Prosthetic design ridge lap/flange
	Deep peri-implant probing depths	Interproximal spaces closed by ceramic restoration or "pink porcelain"
	Bone loss	

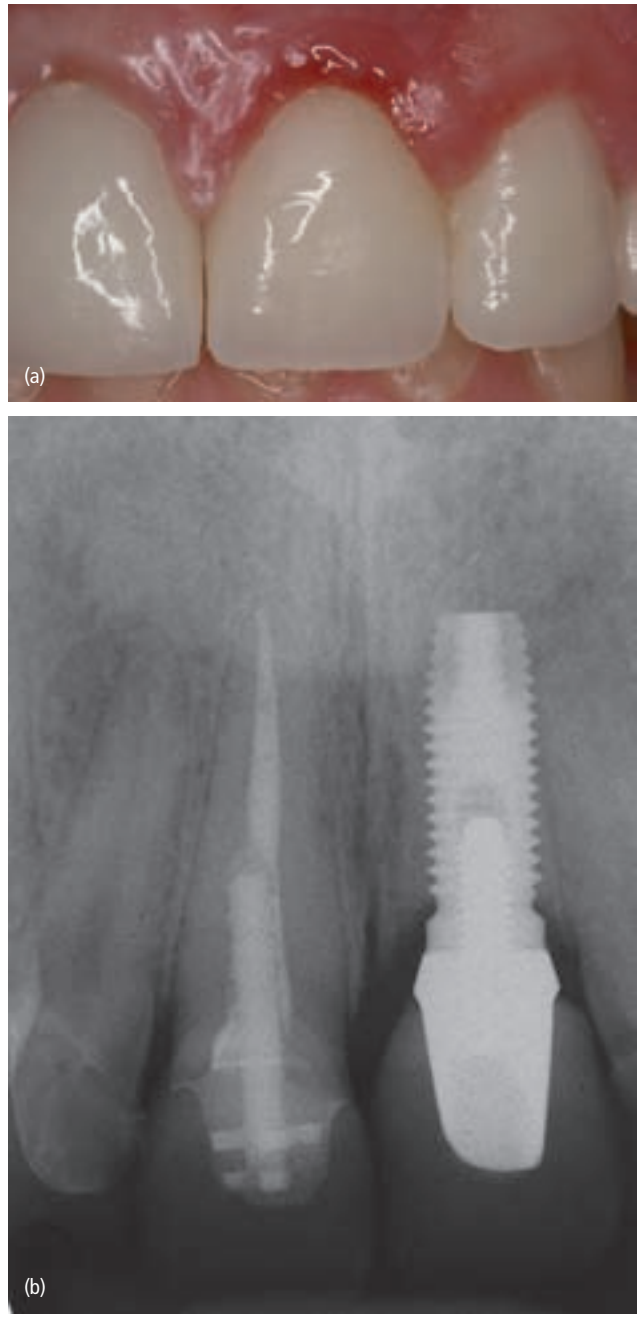


Fig. 23.1 (a) Peri-implant mucositis presenting with changes in color, form, and texture. (b) Peri-implant mucositis presents radiographically with no change in crestal bone

Examination of the peri-implant tissues should be performed both visually and tactilely. Changes in color, form, texture, and the expression of blood and/or suppuration on palpation and probing are changes indicative of inflammatory disease.

An integral part of the assessment phase is ascertaining the bone level surrounding the implant. This is best accomplished radiographically (4). Ideally, a periapical image is taken. These images must be parallel to the implant body and will demonstrate the crestal level on the proximal aspect of the implant, radiolucencies along the implant body, and general patterns of bone destruction (5) (Fig. 23.2b). However, in certain instances periapical radiographs cannot be taken when the mandibular

Table 23.2 Contributing etiologic factors

Bacterial flora	Inadequate plaque control
	Residual periodontal pathogens
	Crevicular depths
	Inadequate/infrequent débridement
	Absence of functional keratinized tissue
	Implant proximity
	Design of restoration
	Exposure of implant surface
Forces	Inadequate number of implants
	Inadequate length/diameter of implants
	Occlusal scheme
	Parafunction
	Loss of teeth and/or implants since completion of original treatment plan
	Biomechanical design of implants
Systemic	Diabetes
	Smoking
	Alcohol
	Medications
	Osteoporosis

ridge and the floor of the mouth are level, or a shallow maxillary vault exists. In these circumstances a panoramic image or computer axial tomograms are necessary.

Changes in bone can only be determined by comparing the current radiographs to those taken at the completion of integration and at the time of placing the permanent restoration. These radiographs should be the same angulations to note changes in the bone-to-implant relationship.

Recording the position of the peri-implant mucosal margin and comparing it with prior observations allows the clinician to identify factors resulting in soft-tissue hyperplasia or recession. Probing of the peri-implant crevice is of limited value in detecting disease. There is no evidence correlating probing depth with the potential for the onset or progression of peri-implant disease (6). Gentle probing circumferentially, using forces significantly less than those used in a periodontal examination, eliciting bleeding and/or suppuration reveals the presence of inflammation.

Bone loss involving the bone crest around an implant can be attributed to etiologic factors that cause peri-implantitis, systemic conditions, medications, and lifestyle habits. The diagnosis of peri-implantitis requires correlating the presence of inflammation with bone loss (3) (Table 23.2) (see Chapter 2).

Etiology

Numerous factors may be responsible for inflammatory peri-implant disease. The maintenance examination should detect these factors and ultimately lead to treatment aimed at eradicating the disease and preventing its recurrence. The primary contributing entity is bacterial plaque. Plaque accumulation can result from inadequate daily removal, lack of débridement at the proper intervals and a prosthetic design that does not provide access for the patient or the therapist to the peri-implant soft-tissue crevice.

Xerostomia, a side-effect of numerous drugs (e.g. antihypertensives, diuretics, antidepressants, and antihistamines), can foster plaque and calculus accumulation that can lead to inflammatory changes in the peri-implant

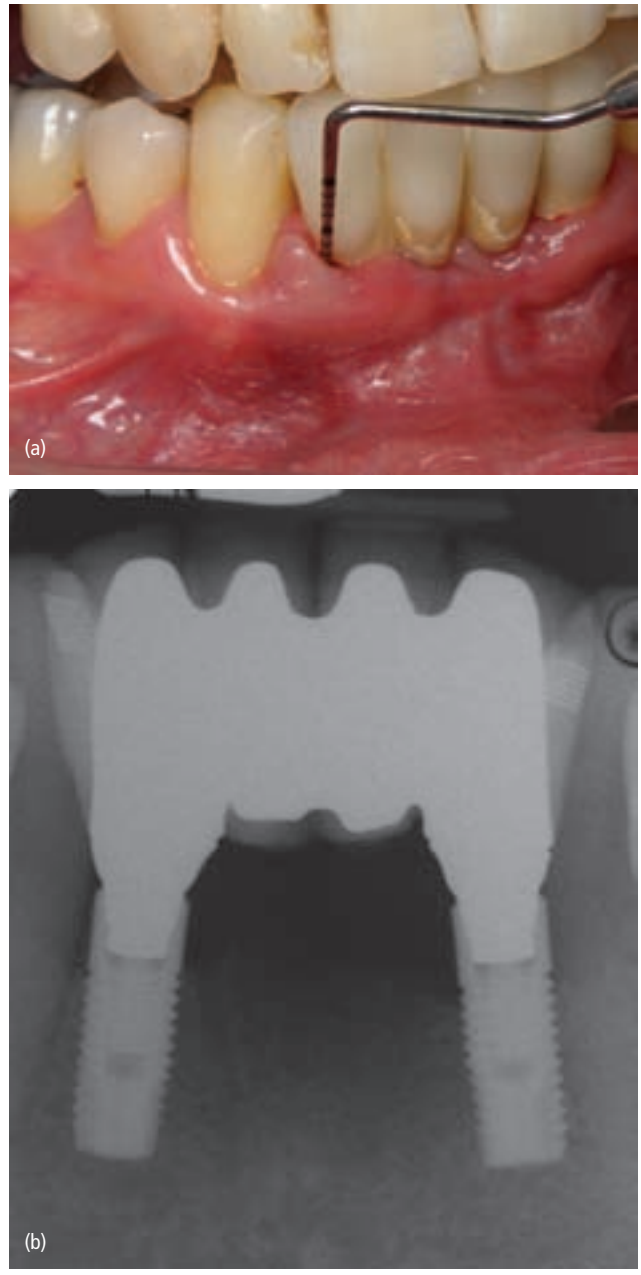


Fig. 23.2 (a) Peri-implantitis presenting with changes in color, form, texture, and associated bone loss resulting in increased probeable depths. (b) Peri-implantitis radiographically demonstrates crestal bone resorption.

tissues. Furthermore, smoking has been reported to compromise immunologic responses to bacteria, thereby contributing to the development and progression of peri-implant disease (7).

Loose restorative components in the vicinity of the peri-implant mucosal margin and the crevice can result in inflammatory changes owing to the accumulation of bacteria between the surfaces of the components (Fig. 23.3). Excess cement at the margin of a restoration within the peri-implant crevice can also induce inflammatory disease (Fig. 23.4a, b).

The position of an implant can influence the design of the restoration. The interface of the implant restoration and the peri-implant mucosal margin should permit access circumferentially for plaque control and débridement. Difficulties can arise if multiple implants are placed with insufficient interproximal space. Inadequate embrasure space between implants and teeth or adjacent implants that preclude access for plaque control and débridement can lead to inflammation in the peri-implant tissues (Fig. 23.5a, b). Provisional and permanent restorations that are not designed to allow the patient to perform effective plaque control can lead to peri-implant disease (Fig. 23.6a, b). Moreover, final restorations using pink porcelain to close interproximal spaces or support the lip should also allow access for both the patient and clinician to clean the peri-implant crevice.

The position of the implant in relation to the osseous and the soft-tissue architecture is an influential factor in facilitating plaque control and débridement. Therefore, the relationship between anatomic environment and the design of the final restoration must be considered during the diagnostic phase. Precipitous angular osseous crests can result in deep crevices and restrict access for plaque control and instruments used for débridement (Fig. 23.7). This can also occur when implants are inserted too far apically relative to the osseous crest and soft-tissue margin. Restorative designs including ridge laps or hybrid prostheses, which attempt to compensate for esthetic and phonetic issues and restrict access to the peri-implant crevices, can contribute to peri-implant disease (Fig. 23.8a–d).

The nature of the soft tissue surrounding the implant as it emerges into the oral cavity can influence the efficacy of a patient's plaque control. A shallow crevice provides

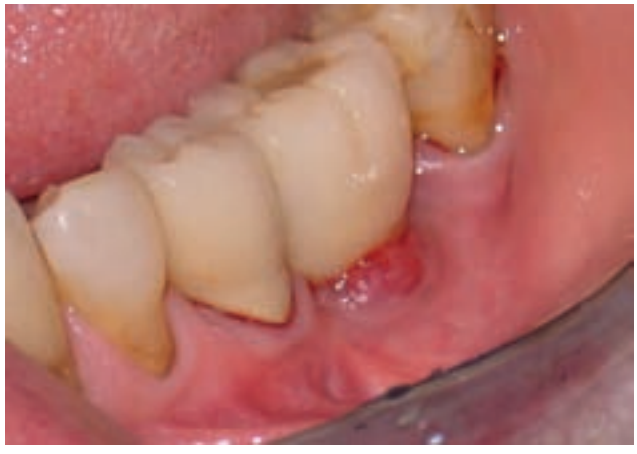


Fig. 23.3 Loose implant crown causing an inflammatory reaction in peri-implant tissues.

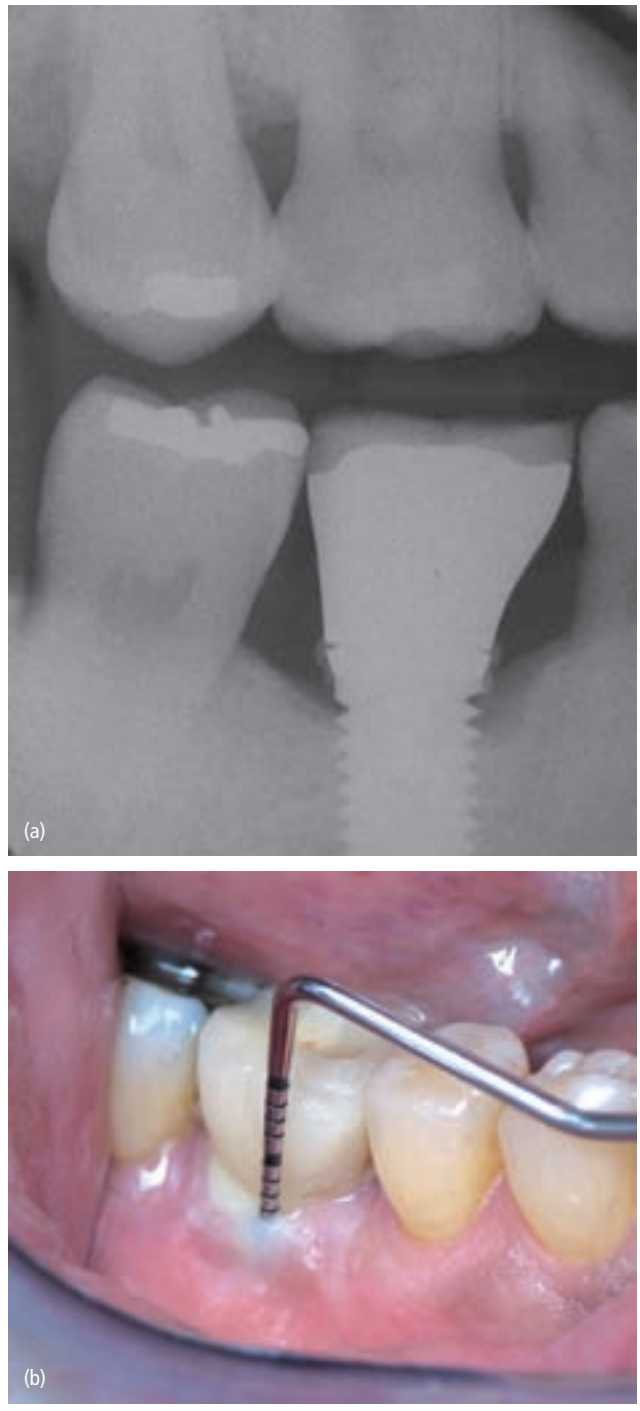


Fig. 23.4 (a) Parallel film showing retained cement and bone destruction around an implant. (b) Peri-implantitis with suppuration induced by excess cement.

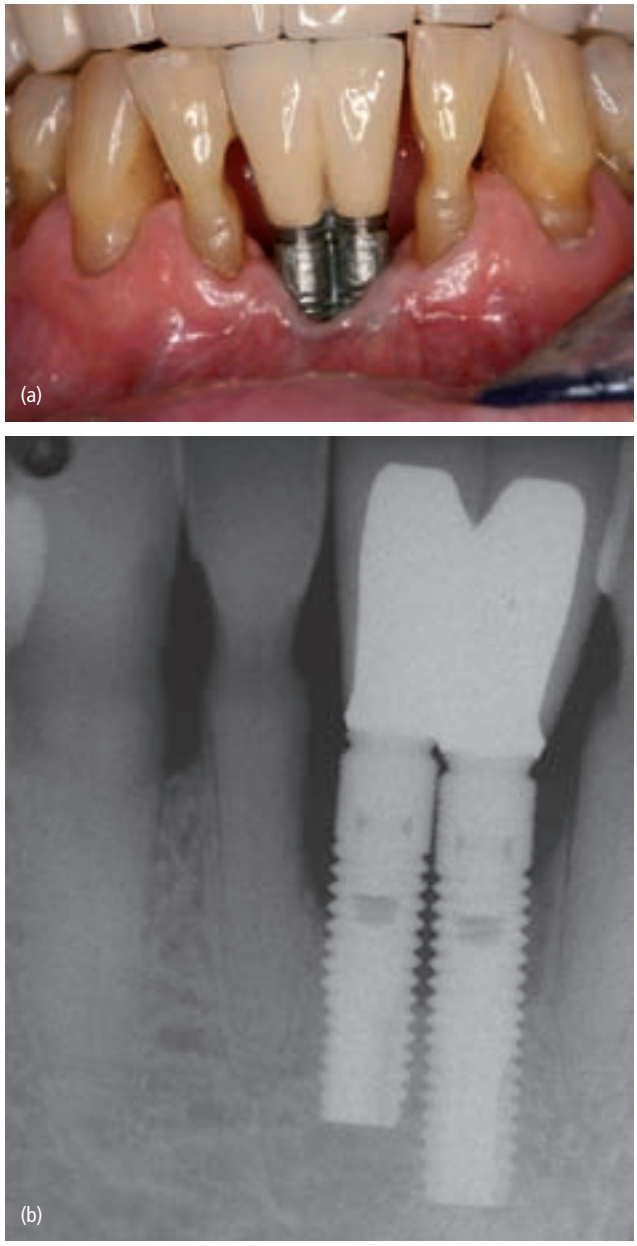


Fig. 23.5 (a) Non-maintainable situation due to implant proximity. (b) Bone loss due to implant proximity

an environment that is more conducive to minimizing plaque accumulation (8). Implants intentionally placed in a deep crevice to permit the development of a proper emergence profile create a more challenging environment for the clinician and the patient to clean.

The presence of a circumferential zone of attached keratinized tissue appears to be less prone to inflammatory peri-implant disease (9, 10). The absence of keratinized tissue can be associated with bone loss, as evidenced by recession, exposure of restorative margins, exposure of the implant body, and a vulnerability to inflammation and discomfort when the patient performs plaque control (11) (Fig. 23.9).

Fig. 23.6 (a) Soft-tissue reaction to provisional restoration with contours that interfere with effective plaque control. (b) Provisional restoration with contours that interfere with plaque control.

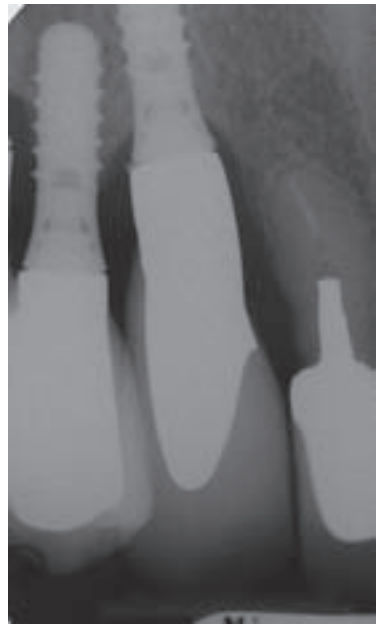


Fig. 23.7 Implant placement resulting in a peri-implant crevice that is inaccessible for plaque control and débridement.

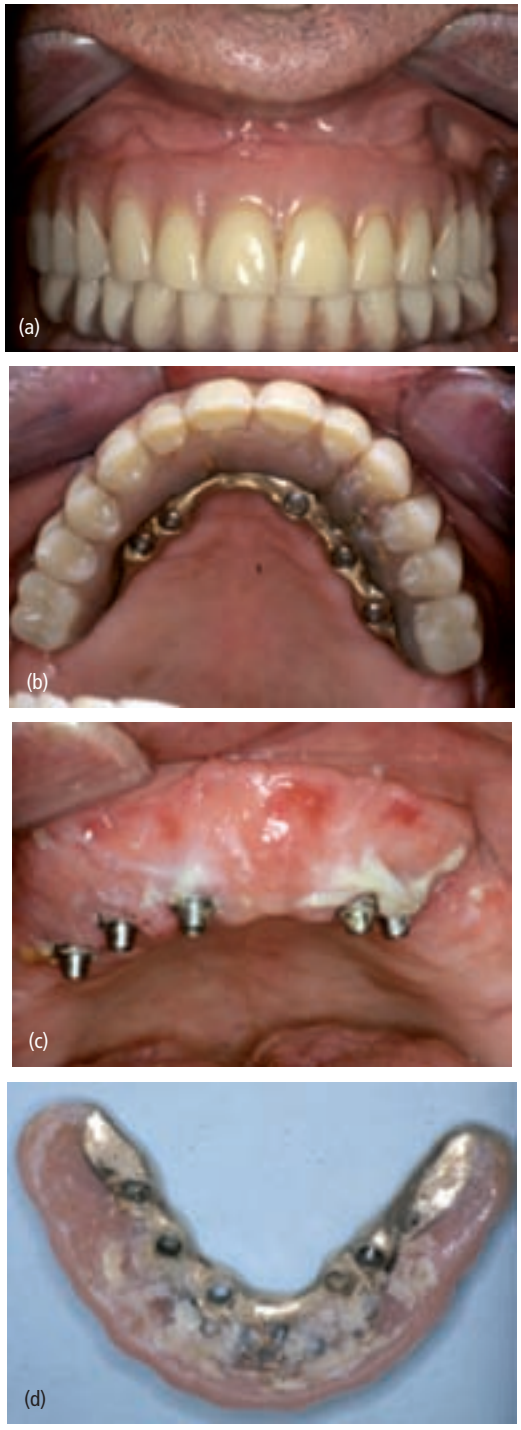


Fig. 23.8 (a) Facial view of a fixed maxillary hybrid prosthesis with a flange that interferes with plaque control. (b) Palatal view. (c) Tissue surface under hybrid prosthesis in reaction to non-cleansable environment. (d) The tissue surface of the maxillary hybrid prosthesis seen in (a).

The loss of bone results in exposure of the implant body, presenting a surface that is very difficult to clean for both the patient and therapist (Fig. 23.10). The exposure of the implant surface can also occur within a deepening peri-implant crevice.

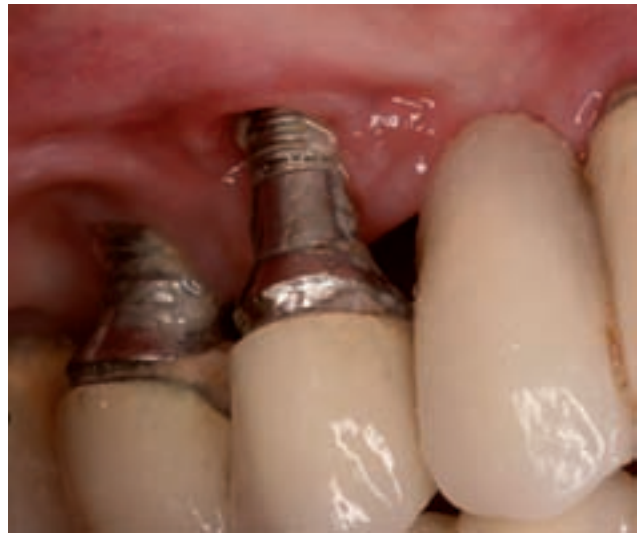


Fig. 23.9 Lack of keratinized tissue presents a difficult site for a patient to maintain.

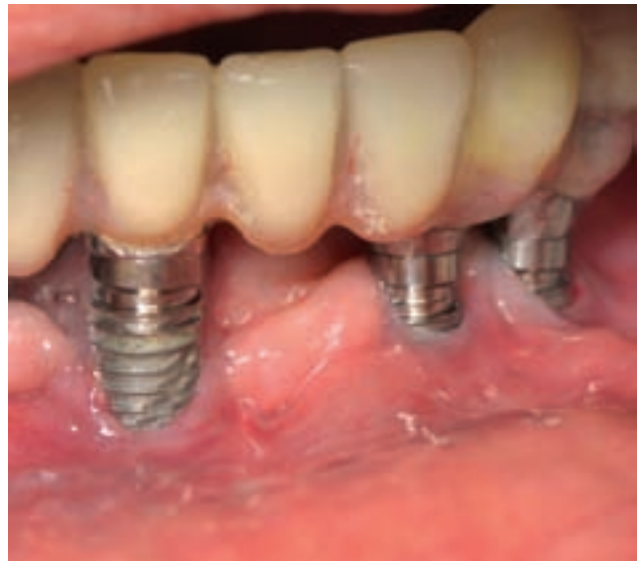


Fig. 23.10 Exposed implant surface that is difficult to maintain.

Prevention

The anatomic characteristics of the soft tissue surrounding the implant and the relationship with the restorative componentry affect the prevention of peri-implant disease.

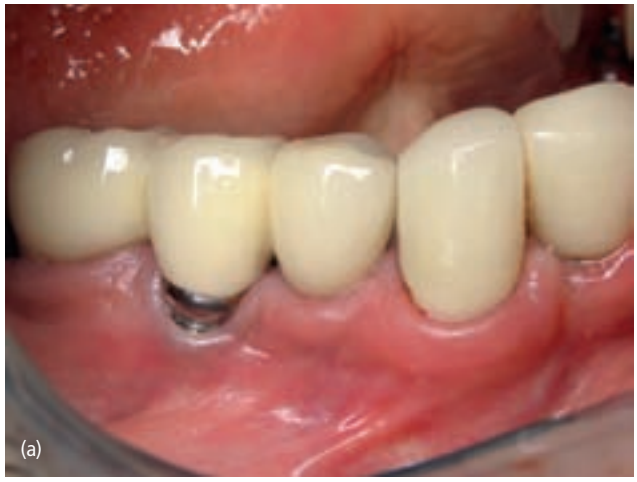
The surgical management of the soft tissue at the time of implant placement with a single-stage protocol, or at the time of uncovering in a two-stage protocol, should be guided by the crevicular depth and the nature of the tissue desired. In the non-esthetic zone a shallow crevice is ideal, creating an environment that is readily maintainable by plaque control techniques and débridement (8). This goal may have to be compromised in the esthetic zone to enable the development of an appropriate emer-

gence profile of the restoration. In the latter instance the crevice should be only as deep as necessary to achieve an esthetic restoration. This outcome is influenced by meticulous planning and proper incisogingival and faciolingual placement of the implant.

Managing the soft tissue relative to crevicular depth and ensuring a circumferential zone of attached keratinized tissue are important considerations for long-term implant maintenance. These goals can be accomplished with repositioned flaps (e.g. apically positioned), pedicle grafts, free soft-tissue autografts, free gingival or connective tissue grafts, subepithelial connective tissue grafts (Fig. 23.11a, b), or acellular dermal matrix grafts.

Maintaining the peri-implant tissues in health must be the responsibility of both the patient and the therapist. Prevention of the recurrence of inflammatory disease involves ongoing plaque control and, where necessary, treatment to alter the environment to facilitate this goal. Initially, the patient's plaque control techniques must be observed and then be modified when necessary to be effective. The clinician must emphasize the need to clean the peri-implant crevice circumferentially. There are many plaque control implements to aid in this process (Table 23.3). Choosing the appropriate aid for the patient may be challenging. The therapist must take into account the motivation of the patient, their manual dexterity, the restorative design, the tissue quality, and the position of the implants in the arch. In addition, local applications of chlorhexidine may be recommended. It is not enough for the therapist to discuss plaque control with the patient; proficiency should be demonstrated by the patient. This may require several follow-up visits. The interval between professional maintenance visits may need to be shortened if a patient is unwilling or unable to maintain proper plaque control.

In general, with a single tooth or unsplinted implant restoration the patient is able to brush and floss into the crevice. The implant restoration may mimic a tooth but the subgingival anatomy can be very different. The implant abutment is usually narrower than the cervix of a natural tooth. The patient needs to adapt the floss to the abutment surface (Fig. 23.12). Patients who do not have the ability to floss should be instructed on how to clean into the crevice using a unitipped power brush, a



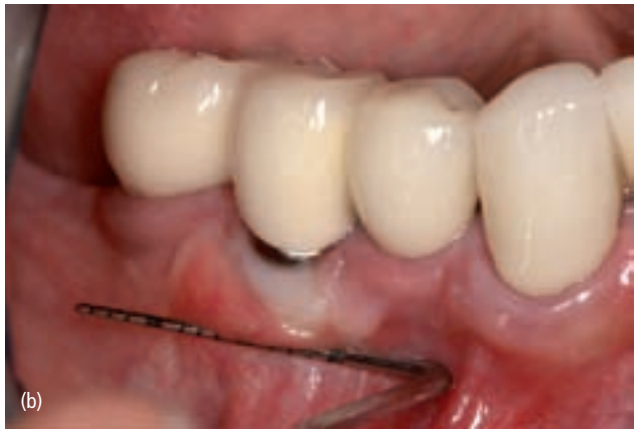


Fig. 23.11 (a) Lack of keratinized tissue before a subepithelial connective tissue graft. (b) Adequate band of keratinized tissue after a subepithelial connective tissue graft.

Table 23.3 Plaque control implements

Type of implement	Examples	Manufacturer
Brush (manual)	Imtec™ Access™ Brush	Imtec, a 3M company, Ardmore, OK, USA
	End Tuft brush	
Powerbrush	Rota-dent®	Zila Inc., Batesville, AR, USA
	Phillips® Sonicare	Phillips Electronics North America Corp, Andover, MA, USA
	Oral-B® Braun Triumph™	Proctor & Gamble Company, Cincinnati, OH, USA
Floss	Teflon Tapes	
	Thornton Floss 3 in 1 floss Periodontal floss Bridge & implant cleaner	Thornton International Inc., Norwalk, CT, USA
	Oral-B Superfloss®	Proctor & Gamble Company, Cincinnati, OH, USA
	GUM® Postcare®	Sunstar Americas Inc., Chicago, IL, USA
Interdental brush	Tapered Thinline	
	Proxytip®	AIT Dental, Beverly Hills, CA, USA
	GUM® Soft picks®	Sunstar Americas Inc., Chicago, IL, USA
	Perio-aide®	Marquis Dental Manufacturing Co., Aurora, CO, USA

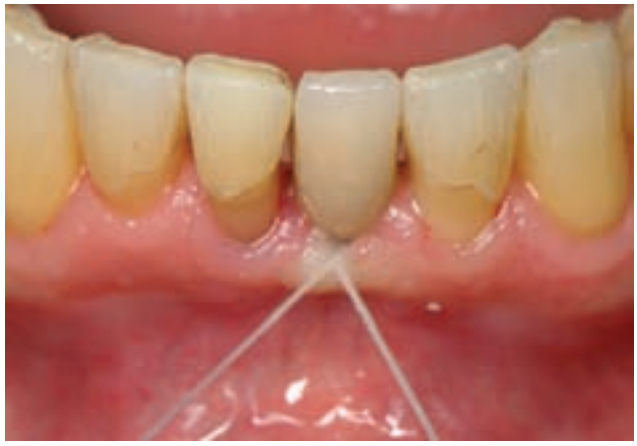


Fig. 23.12 Adaptation of floss to the implant abutment

Perio-aid® (Marquis Dental Manufacturing Co., Aurora, CO, USA), or Gum® Soft-Pick® (Sunstar Americas, Chicago, IL, USA).

Multiunit implant bridges should be designed with sufficient embrasure space to allow the use of a floss threader. Where anatomic situations allow, such as in the posterior region, embrasure spaces can be made with sufficient access for an interdental brush. Power brushes can be more effective than manual brushes for removing plaque (12). Selection of the appropriate brush is dependent on the anatomy of the patient's mouth, patient dexterity, and the restorative design (Fig. 23.13).

Débridement by the therapist at the appropriate interval is dependent on plaque accumulation, the patient's systemic health, and the patient's ability to remove plaque. Removal of all soft and hard accretions, both supramarginally and submarginally, should be performed by the therapist. Many implant restorations are part of a mixed implant–naturally dentated oral environment. There must be a concentrated effort to maintain the periodontal health of the remaining natural teeth together with the health of the peri-implant tissues.

Débridement of the implant-supported restoration must be directed at three components: the prosthesis, the abutment, and the implant fixture surface if it becomes exposed to the oral cavity. The restoration can be débrided as with any other restoration using appropriate instrumentation so as not to damage the restorative material. The abutment needs to be instrumented so as not to damage the integrity of the smooth convex surface. Metal instruments designed for the natural dentition have been shown to be injurious to the abutment surface (13). Plastic scalers and curettes are available in many configurations which will adapt to the abutment surface without inducing damage (14, 15) (Fig. 23.14). Power instruments, piezo tips, ultrasonic inserts, and Eva tips (Dentatus USA, New York, NY, USA), which are designed to maintain the integrity of the surface and are capable of removing any hard accretions, are also useful

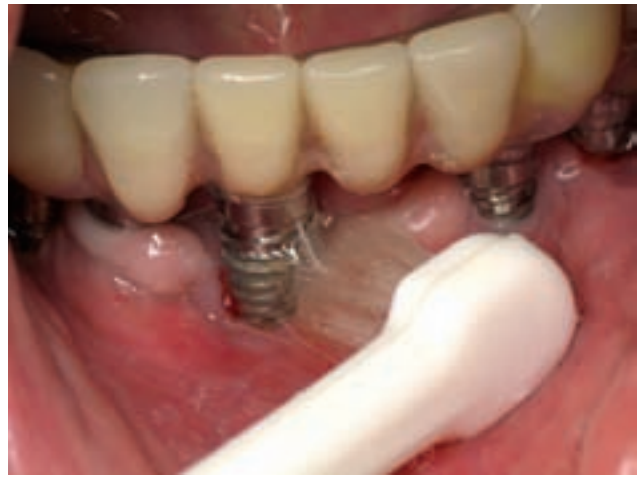


Fig. 23.13 End tuft brush: the best choice for a restorative design that anatomically makes it difficult for a full-size brush head.

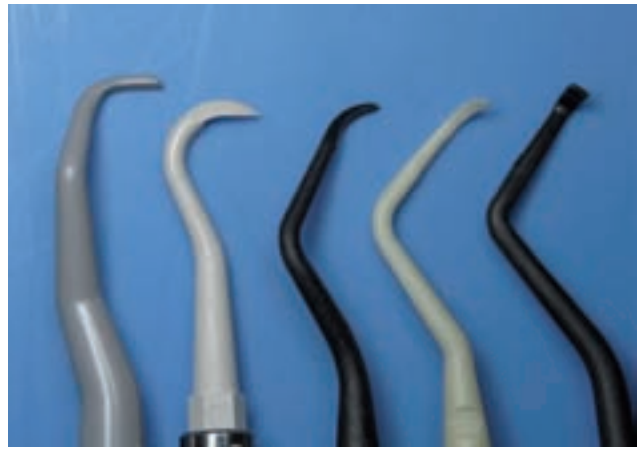


Fig. 23.14 Different configurations of plastic scalers and curettes are available.

Table 23.4 Débridement instruments

Type of instrument	Examples
Manual	Hu-Friedy® Implacare Premier® Implant curettes Advanced Implant Technologies® Prophy + Surgical Innovations
Power	Tony Riso Co. TIS scaler Satellec Piezo carbon tips Profin Eva tip

(Fig. 23.15, Table 23.4) (16, 17). These power instruments should only be used on low power settings. Soft debris can be removed from the abutment surface using homecare aids (Table 23.3). If the implant surface becomes exposed it must be débrided. Calculus on the implant surface can be very tenacious and difficult to remove due to the microstructure and macrostructure. Using metal instruments on the rough or threaded implant surface is an effective way to remove calculus (Fig. 23.16).

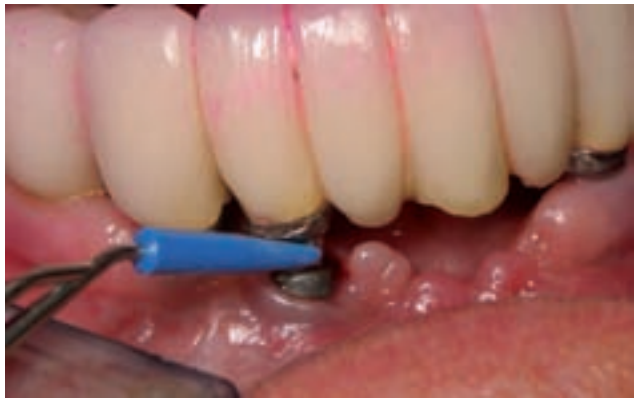


Fig. 23.15 Ultrasonic insert designed for implant abutments.

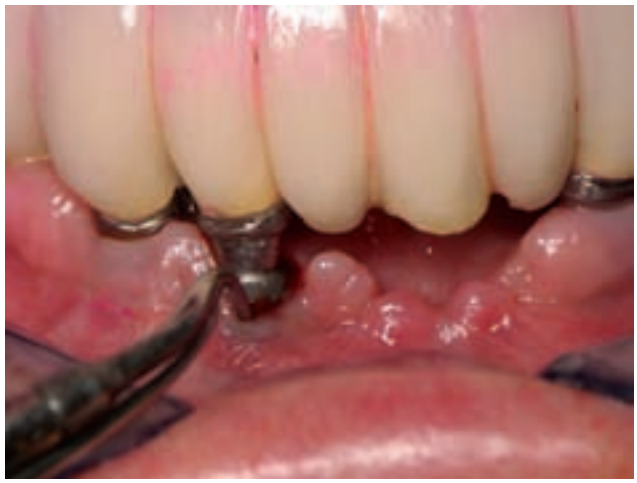


Fig. 23.16 Metal cavitron tip débriding an exposed implant fixture surface.

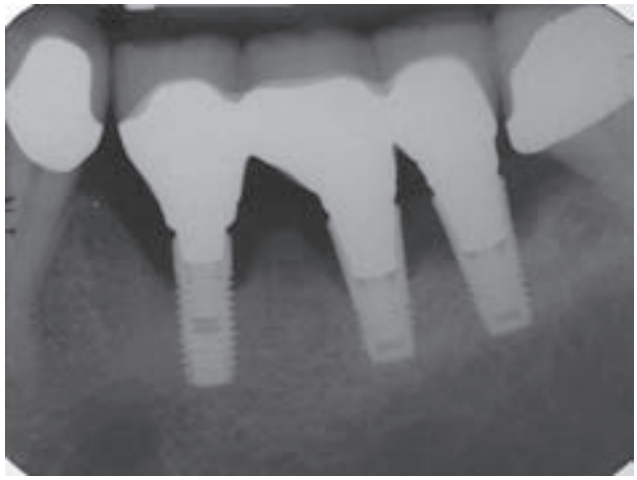


Fig. 23.17 Radiograph of saucerized infrabony lesions associated with peri-implantitis.

Treatment

Treatment of peri-implant mucositis and peri-implantitis is directed at arresting the process by controlling the etiology and correcting any contributing factors (see Chapter 7). Initially, all plaque and calculus above and below the peri-implant mucosal margin should be removed. This may be accomplished with plaque control implements, hand instruments and power instruments (Tables 23.3, 23.4).

Antibiotics and antimicrobials can be prescribed. Upon the resolution of the inflammation the resultant cervicular depth should be evaluated to determine whether it can be kept free of inflammation with plaque control and professional maintenance care performed at appropriate intervals.

However, if the crevicular depth is too great to be maintained in a state of health, pocket elimination therapy is indicated. This occurrence is most commonly encountered where peri-implantitis has resulted in the loss of bone surrounding the implant (see Chapter 7). The saucerized infrabony lesion (Fig. 23.17) associated with peri-implantitis has been reported to be managed by a variety of techniques. Surgical procedures to treat peri-implant osseous defects include:

- open flap débridement
- open flap débridement with laser treatment
- bone grafting
- guided tissue regeneration
- resective osseous surgery
- combination regenerative therapy.

Grafting these defects with various materials in some instances has resulted in obturation and reduced crevicular depths. Reosseointegration on an implant surface that has been exposed to the oral cavity has been demonstrated to be difficult to achieve (18). Resective osseous surgery with apically positioned flaps is another method of eliminating these defects and creating a hard- and soft-tissue anatomy that is maintainable. Limited data are currently available on the use of laser therapy to manage these lesions (19).

In sites that lack keratinized tissue soft-tissue augmentation procedures may be performed. A variety of techniques, employed for periodontal mucogingival surgery, has been successfully used for this purpose (see Prevention subsection, above).

An exposed implant surface presenting a roughened macroarchitecture and microarchitecture retains plaque and calculus and limits plaque control and débridement procedures. Rendering the surface smooth by grinding and polishing has been suggested to reduce debris retention (20).

If the inflammation is related to restorative component or design problems appropriate corrections must be made. Fractured screws must be replaced. Loose screws must be tightened. Removal of excess cement is essential to prevent iatrogenic bone loss. Loss of a cement seal requires recementation. A fractured fixture can be removed and replaced if its support is necessary or it can be submerged with soft tissue and allowed to "sleep"

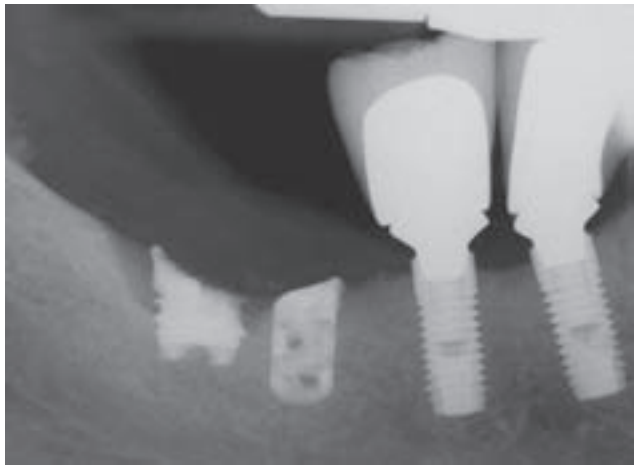


Fig. 23.18 Fractured implants sleeping due to proximity to mandibular canal.

(Fig. 23.18). However, these submerged implants have the potential to act as irritants resulting in pathologic responses and must be monitored closely. Reshaping or replacing restorations that impede access to the peri-implant crevice for plaque control and/or débridement may also be necessary to enable long-term maintenance of the implant restoration.

Loss of stability of restorative components

The loss of integrity of the relationship between any of the restorative components can have a dual implication. It can be a result of an unrecognized or uncontrolled factor as well as being a contributing etiology. The connection between the restoration, the abutment, and the implant should be tested during the assessment phase to detect looseness. In a multiunit restoration the clinician can apply force interproximally in an occlusal direction to detect loss of a ridged connection. Single units can be tested as one would evaluate a tooth for mobility. The presence of looseness may also be due to fracture of a screw or even the implant itself (Fig. 23.19a, b) (see Chapter 5). Another underlying problem can be the loss of implant integration. Scrutiny of the occlusal surfaces may reflect wear patterns indicative of parafunction.

The loss of the intimacy of fit between components provides space for the proliferation of bacteria. During function bacteria and their metabolic products are expressed into the peri-implant crevice, and contribute to the development and progression of peri-implant disease.

Numerous factors have been reported to be related to screw loosening and fracture (see Chapters 5 and 21). The loosening of abutments and restorations can result in damage such as screw fracture and distortion of the threads within the implant. In a multiunit restoration in which some components become loose, other components that remain rigid can receive forces greater then they can tolerate, resulting in damage (21).

Etiology

The manifestation of loose restorative components including fractures most commonly can be related to the magnitude, frequency, duration, and direction of the forces of function (21). These problems were experienced more often in the early years of osseointegrated implant dentistry and were attributed to screw and thread design,

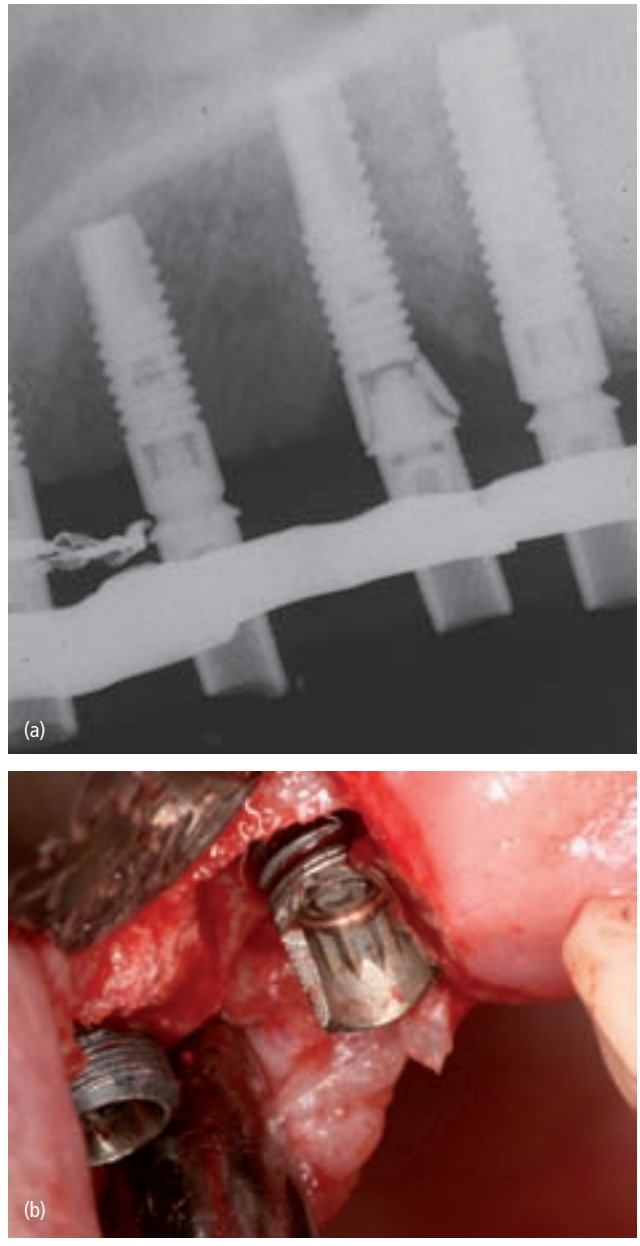


Fig. 23.19 (a) Radiograph of a fractured implant. (b) Clinical presentation of the fractured implant seen in (a).

materials from which the components were fabricated and inadequate preload. The number of implants, implant length and diameter, implant position, the restorative design, and the occlusal scheme influence the transmission and absorption of occlusal forces.

Parafunctional habits can generate forces that exceed the tolerance of the restorative components, contributing to fatigue fracture. Patients who are taking selective serotonin reuptake inhibitors (SSRIs) have been reported to have an increased incidence of bruxism (22).

Excessive occlusal forces have been shown to result in the loss of integration (23) (see Chapter 21). The ability to resist force and preserve integration is related to the amount of bone-to-implant contact and the density of the peri-implant bone. Implant fracture has been recorded secondary to bone loss due to a change in the fulcrum of the forces of function (24) (see Chapter 6).

Medications, systemic disease and lifestyle habits can deleteriously affect the bone homeostasis and result in late implant failure (see Chapter 6). Cyclosporin, glucocorticosteroids, and SSRIs are being prescribed on a more frequent basis. All of them affect bone remodeling and result in a decrease in bone density. Proton pump inhibitors diminish calcium absorption, thereby impacting bone metabolism and density. Bisphosphonates are administered orally to manage osteoporosis and osteopenia and those given intravenously to control bone resorption in patients with multiple myeloma, metastatic disease of the skeleton, hypercalcemia of malignancy, and Paget's disease have been associated with the development of osteonecrosis of the jaw (25).

An extensive list of systemic diseases can influence the continued success of osseointegration (see Chapter 2). Two will be discussed based on the frequency of expression in patients treated with implant dentistry. Diabetes (type 2) has become epidemic. Implants in uncontrolled diabetics and even in well-controlled patients have a reduced success and survival rate (26). Bone remodeling is also compromised in the presence of hyperglycemia (27). Therefore, early detection of this metabolic disorder is important in helping to sustain osseointegration.

Osteoporosis is another disease that affects males as well as females with increasing prevalence due to an aging population and the trend away from using hormone replacement therapy for women entering menopause. Osteoporosis results in a diminution in bone density.

Lifestyle habits also influence bone density. The retardation of bone formation secondary to smoking is related to a reduction in endothelial cell, fibroblast, and osteoblast proliferation. A clinical complication associated with this is the loss of integration, manifest as a late failure after the implant is loaded. The reduced quality and quantity of bone-to-implant contact is vulnerable to the forces of occlusal function (28).

Another lifestyle habit that has been shown to influence bone formation negatively is alcohol consumption (29, 30). The amount of alcohol consumed by a patient may influence changes in the bone surrounding the implant.

Prevention

The prevention of component loosening and fracture depends on proper initial diagnosis and treatment planning. Recognition of the potential forces that will be generated in function and parafunction are important factors in the selection of an implant with the appropriate biomechanical characteristics and will aid in determining the number of implants, their dimensions, and positioning. The design of the restoration, the occlusal scheme, the materials used, and whether restorations are screw or cement retained are important considerations.

An occlusal guard in patients with parafunctional habits is an essential preventive device giving protection to the restoration, restorative components, the implant, and the bone–implant interface. Patients who develop neurologic disorders, such as Parkinson's disease, or are taking SSRIs will also benefit from this type of an appliance due to extreme parafunctional habits.

The loss of integration of an implant in the absence of peri-implantitis may be related to a change in the bone-to-implant contact and/or a reduction in the density of the peri-implant bone. Changes observed in radiographs should raise concern regarding a systemic influence (see Chapter 2).

Patients who have been diagnosed with and are being treated for diabetes and osteoporosis should be questioned at the preventive care visit regarding compliance with treatment and the frequency of follow-up by the physician. Specifically, the diabetic patient's blood sugar level and control should be noted. The glycosylated hemoglobin (HbA_{1c}) is a useful test to track blood glucose levels over a 90-day period.

Patients taking various medications that affect bone metabolism require more frequent clinical and radiographic examination.

Guidelines to prevent osteonecrosis of the jaw secondary to bisphosphonates have stressed the need for strict and meticulous preventive care to preclude the onset of inflammatory disease (25, 31, 32).

The clinician should counsel patients regarding the influence of tobacco and alcohol consumption on peri-implant health.

Treatment

Treatment of the loss of stability of restorative components can range from the simple to the complex. In the absence of damage to any of the components as a cause of or as a result of the loss of stability, merely tightening screws or recementation of the prosthesis may solve the problem.

The loss of function of an implant as a result of fracture or deintegration may require its removal and replacement. Placement of additional implants may be indicated to distribute more effectively the forces of function or compensate for a diminution in bone density. Redesign of the restoration can be part of the solution in managing the direction of forces.

Peri-implant mucosal hyperplasia

Hyperplasia of the peri-implant mucosa favors the accumulation of a greater quantity of bacteria, fostering the development of inflammation. This niche is ecologically preferential for the proliferation of species associated with peri-implantitis.

The resultant soft-tissue form creates difficulty for the patient to perform effective plaque control. The therapist can also encounter difficulties with débridement procedures.

Etiology

The development of soft-tissue hyperplasia around implants and under the suprastructure bars retaining overdentures has been reported. The mechanism for this occurrence has not been explained.

A variety of medications has been demonstrated to cause peri-implant mucosal hyperplasia, such as phenytoin (Dilantin), calcium channel blockers, cyclosporin, and amphetamine.

The deepened crevice that favors bacterial proliferation and interferes with mechanical removal, resulting in inflammation, further stimulates hyperplasia and potentially loss of peri-implant bone. The situation is further complicated by the quantitative and qualitative change that occurs within 90 days in the crevicular flora in patients taking immunosuppressive therapy (cyclosporin) (33). Changes in either the patient's medication or the preventive care regimen are essential to preclude the development of the deformities associated with peri-implantitis.

Prevention

Minimizing proliferation of the soft-tissue hyperplasia secondary to medications requires meticulous plaque control. Training patients to use the appropriate implements, topical application of chlorhexidine, and frequent débridement are necessary to prevent peri-implant inflammatory disease.

Treatment

Consultation with the prescribing physician may result in substituting a medication that does not induce soft-tissue hyperplasia. A change in medication often results in resolution of the tissue overgrowth. In instances when the medication cannot be changed surgical reduction using gingivectomy/gingivoplasty or flap techniques is indicated. Surgical retreatment is indicated when the soft-tissue deformity recurs.

Conclusion

The ultimate goal of maintenance care in implant dentistry is to prevent disease of the peri-implant tissues and damage to the restorative components. Frequent, thorough, and insightful assessment will detect complications that occur during this long-term care. Complications are anticipated in the face of inadequate monitoring and intervention specifically resulting from insufficient plaque control by the patient and/or infrequent débridement by the therapist. Improper treatment planning, suboptimal surgical and restorative outcomes as they relate to implant placement, and poor soft-tissue management or restorative design can contribute to complications arising during the preventive care phase. Even with optimal treatment planning, surgical and restorative execution, and a strict preventive regimen, complications may occur as a result of a change in the systemic status of the patient. This circumstance reinforces the need to consistently review all details of the patient's medical status and to develop an appreciation for even the most subtle clinical changes.

Understanding the etiology of a complication is fundamental to developing a strategy for corrective intervention and preventing progressive and recurrent problems. Despite strict monitoring and protocol to enhance the long-term prognosis of implant dentistry, certain systemic issues do not lend themselves to definitive solutions. In these cases the clinician, together with the patient and his or her physician, must work to minimize the occurrence of complications.

Take-home hints

- Review the medical history at each preventive care visit.
- Identify any changes in the peri-implant tissue during clinical and radiographic examination. Determine whether changes can be correlated with local or systemic disease/disorder.
- Evaluate supramarginal and submarginal plaque control.
- Take radiographs at the proper intervals and compare them to previous records.
- Evaluate the rigidity of restorative component connections.
- Review plaque control techniques when a patient is provisionalized and at each preventive care visit.

References

1. McDermott NE, Chuang S-K, Woo VV, Dodson TB. Complications of dental implants: identification, frequency, and associated risk factors. *Int J Oral Maxillofac Implants* 2003; **18**: 848–55.
2. Kaufman DW, Kelly JP, Rosenberg L, Anderson TE, Mitchell AA. Recent patterns of medication use in the ambulatory adult population of the United States. The Sloan Survey. *JAMA* 2002; **287**: 337–44.
3. Albrektsson T, Isidor F. Consensus Report of Session IV. In: Lang NP, Karring T, eds. *Proceedings of the First European Workshop on Periodontology*. London: Quintessence, 1994: 365–9.
4. Isidor F. Clinical probing and radiographic assessment in relation to the histologic bone level at oral implants in monkeys. *Clin Oral Implants Res* 1997; **8**: 255–64.
5. Begoña Ormaechea MB, Millstein P, Hirayama H. Tube angulation effect on radiographic analysis of the implant–abutment interface. *Int J Oral Maxillofac Implants* 1999; **14**: 77–85.
6. Weber HP, Crohin CC, Fiorellini JP. A 5-year prospective clinical and radiographic study of non-submerged dental implants. *Clin Oral Implants Res* 2000; **11**: 144–53.
7. Baig MR, Rajan M. Effects of smoking on the outcome of implant treatment: a literature review. I*ndian J Dent Res* 2007; **18**: 190–5.
8. Quirynen M, Papaioannou W, van Steenberghe D. Intraoral transmission and colonization of oral hard surfaces. *J Periodontol* 1996; **67**: 986–93.
9. Block MS, Gardiner D, Kent JN, Misiek DJ, Finger IM, Guerra L. Hydroxyapatite-coated cylindrical implants in the posterior mandible. 10 year observations. *Int J Oral Maxillofac Implants* 1996; **11**: 626–33.
10. Warrer K, Buser D, Lang NP, Karring T. Plaque-induced peri-implantitis in the presence or absence of keratinized mucosa. An experimental study in monkeys. *Clin Oral Implants Res* 1995; **6**: 131–8.
11. Bouri A, Bissada N, Al-Zaharni MS, Faddoul F, Nouneh I. Width of keratinized gingiva and the health status of the supporting tissues around dental implants. *Int J Oral Maxillofac Implants* 2008; **23**: 323–6.
12. Sicilia A, Arregui I, Gallego M, Cabezas B, Cuesta S. A systemic review of powered vs manual toothbrushes in periodontal cause-related therapy. *J Clin Periodontol* 2002; **29** (Suppl 3): 39–54, Discussion 90–1.
13. Rapley JW, Swan RH, Hallmon WW, Mills MP. The surface characteristics produced by various oral hygiene instruments and materials on titanium implant abutments. *Int J Oral Maxillofac Implants* 1990; **5**: 47–52.
14. Homiak AW, Cook PA, DeBoer J. Effect of hygiene instrumentation on titanium abutments: a scanning electron microscopy study. *J Prosthet Dent* 1992; **67**: 364–9.
15. Cross-Poline GN, Shaklee RL, Stach DJ. Effect of implant curets on titanium implant surfaces. *Am J Dent* 1997; **10**: 41–5.
16. Kawashima H, Sato S, Kishida M, Yagi H, Matsumoto K, Ito K. Treatment of titanium dental implants with three piezoelectric scalers: an *in vitro* study. *J Periodontol* 2007; **78**: 1689–94.
17. Sato S, Kishida M, Ito K. The comparative effect of ultrasonic scalers on titanium surfaces: an *in vitro* study. *J Periodontol* 2004; **75**: 1269–73.
18. Wetzel AC, Vlassis J, Caffesse RG, Hamemrle CHF, Lang NP. Attempts to obtain re-osseointegration after experimental peri-implantitis in dogs. *Clin Oral Implants Res* 1999; **10**: 111–19.
19. Romanos GE, Nentwig GH. Regenerative therapy of deep peri-implant infrabony defects after CO_2 laser implant surface decontamination. *Int J Periodontics Restorative Dent* 2008; **28**: 245–55.
20. Meffert RM. Maintenance and treatment of the ailing and failing implant. *J Indiana Dent Assoc* 1994; **73**: 22–4.
21. Rangert B, Krogh PH, Langer B, Van Roekel N. Bending overload and implant fracture: a retrospective clinical analysis. *Int J Oral Maxillofac Implants* 1995; **10**: 326–34.
22. Lobbezoo F, van Denderen RJ, Verheij JG, Naeije M. Reports of SSRI-associated bruxism in the family physician's office. *J Orofac Pain* 2001; **14**: 340–6.
23. Isidor F. Influence of forces on peri-implant bone. *Clin Oral Implants Res* 2006; **17** (Suppl 2): 8–18.
24. Rangert B, Jemt T, Jörneus L. Forces and moments on Brånemark implants. *Int J Oral Maxillofac Implants* 1989; **4**: 241–7.
25. Migliorati CA, Casiglia J, Epstein J, Jacobsen PL, Siegel MA, Woo SB. Managing the care of patients with bisphosphonate associated osteonecrosis. *J Am Dent Assoc* 2005; **136**: 1658–68.
26. Fiorellini J, Chhen PK, Nevins M, Nevins M. A retrospective study of dental implants in diabetic patients. *Int J Periodontics Restorative Dent* 2000; **20**: 367–73.
27. Nevins ML, Karimbux NY, Weber HP, Giannobile WV, Fiorellini JP. Wound healing around endosseous implants in experimental diabetes. *Int J Oral Maxillofac Implants* 1998; **13**: 620–9.
28. Cesar-Neto JB, Duarte PM, Sallum EA, Barbieri D, Moreno H Jr, Nociti FH Jr. A comparative study on the effect of nicotine administration and cigarette smoke inhalation on bone

healing around titanium implants. *J Periodontol* 2003; **74**: 1454–9.
29. Chakkalaka DA. Alcohol-induced bone loss and deficient bone repair. *Alcohol Clin Exp Res* 2005; **29**: 2077–90.
30. Bombonato-Prado K, Brentegani LG, Thomazini JA. Alcohol intake and osseointegration around implants: a histometric and scanning electron microscopy study. *Implant Dent* 2004; **13**: 238–44.
31. American Dental Association Council on Scientific Affairs. Dental management of patients receiving oral bisphosphonate therapy. Expert panel recommendations. *J Am Dent Assoc* 2006; **137**: 1144–50.
32. Edwards BJ, Hellstein JW, Jacobsen PL, Kaltman S, Mariotti A, Migliorati CA. Updated recommendations for managing the care of patients receiving oral bisphosphonate therapy. An advisory statement from the American Dental Association Council on Scientific Affairs. *J Am Dent Assoc* 2008; **139**: 1674–7.
33. Saraiva L, Lotufo RF, Pustiglioni AN, Silva HT Jr, Imbronito AV. Evaluation of subgingival bacterial plaque changes and effects on periodontal tissues in patients with renal transplants under immunosuppressive therapy. *Oral Surg Oral Med Oral Pathol Oral Radiol Endodontol* 2006; **101**: 457–62.

Chapter 24

Medicolegal issues related to implant complications

Edwin J. Zinman DDS, JD

Etiology of malpractice litigation

Incidence of litigation

Over 10 000 medical malpractice payments (settlements or judgments) to injured patients are made in the USA every year. The overwhelming majority (over 97%) of payments in malpractice cases result from out-of-court settlements rather than jury or judge verdicts (1). All payments – out-of-court settlements or jury verdicts – must be reported to the National Practitioner Data Bank, and are not available to the public.

For those malpractice lawsuits that are tried before a jury or judge, over 70% result in a defense verdict (2). These favorable odds should not necessarily encourage the dentist placing or restoring implant (DPRI) clinician who has been sued to take a case to trial. Many meritorious cases settle out of court. Thus, jury trials are likely to favor the defendant DPRI clinician, since the clearly negligent cases often settle before trial, which skews the statistical outcome of jury trials. Most dental malpractice policies require the dentist's consent to settle. Some policies state that the dentist is responsible for the difference between a carrier's settlement offer and a jury verdict (3).

In recent years, the total number of civil lawsuit claims of medical/dental malpractice as well as autoaccidents has declined, according to the National Center for State Courts (Figs 24.1, 24.2). Notwithstanding the decline in the number of such lawsuits, the average individual claim dollar amount for malpractice payments (settlements and judgments) is rising. For example, in 2008, a wrongful death claim due to conscious sedation overdose settled for $3.9 million (4). The Illinois Dental Board also disciplined the involved endodontists with probation due to substandard dental work and failure to maintain accurate records. In 2008, a Spokane, Washington jury awarded $14.8 million against an oral surgeon for a botched allegedly unnecessary temporomandibular joint surgery which left a 29-year-old patient unable to open her jaws (5).

A 2009 New Jersey wrongful death suit against an oral surgeon for failure to obtain medical clearance before oral surgery resulted in an $11 million verdict (6).

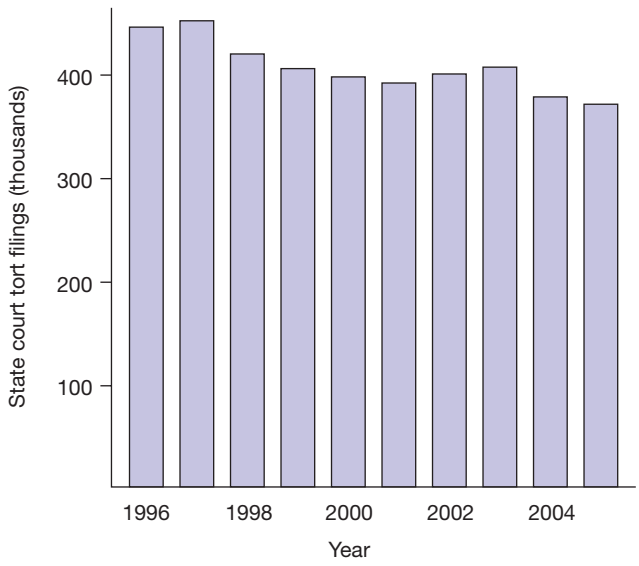


Fig. 24.1 State court tort filings 1996–2004.

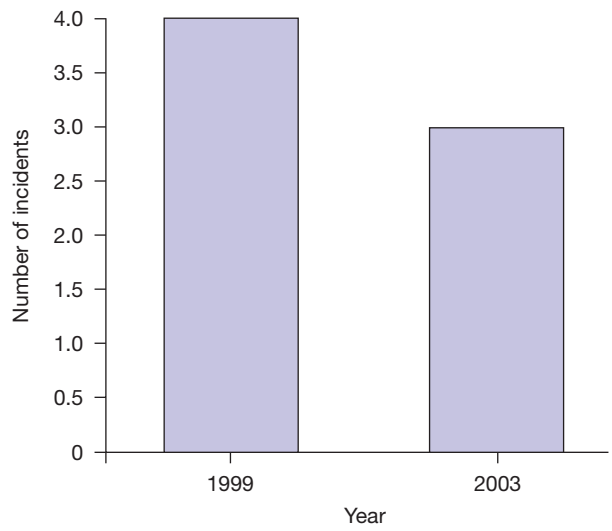


Fig. 24.2 Rate of malpractice incidence 1999–2003. (Source: ADA review of 80 000 insured dentists.)

Etiology of implant-related legal claims

In one study of dental malpractice claims, complications due to implant procedures had the third highest claims incidence (7). The high incidence of implant-related claims likely is due, in part, to the ever-increasing frequency of dental implant placement. General dentists were the primary targets of negligence claims involving dental implant surgery. Implants placed improperly in anatomic locations, which caused an implant's inability to be utilized or restored, generated the most frequent implant claims (7) (see Chapter 8).

This author's experience corroborates reports that implant-related claims are on the rise. Implants drilled or placed into the inferior alveolar nerve canal (IANC), with resultant numbness (paresthesia or anesthesia) and/or burning painful dysesthesia, are the genesis of most litigated implant cases. Typically, the surgeon not only placed the implant without computer axial tomographic (CAT) scan or cone beam computed tomographic (CBCT) imaging, but also failed to promptly remove the implant or refer the patient for immediate postoperative imaging when the patient complained of postoperative numbness and/or burning pain within 24 hours of implant placement. CT imaging can differentially diagnose whether an implant has penetrated the IANC, thus necessitating immediate backing out or removal. For instance, a Los Angeles jury awarded a woman $1.7 million against a periodontist and the general dentist practice owner after the periodontist placed an implant completely through the IANC (Fig. 24.3), causing permanent disabling dysesthesia. Consequently, the patient was unable to continue her nursing career. The defendant periodontist used a medical CT preoperatively, but apparently was inexperienced or unskilled in utilizing and/or interpreting medical CT imaging for preimplant measurements (see Chapter 4).

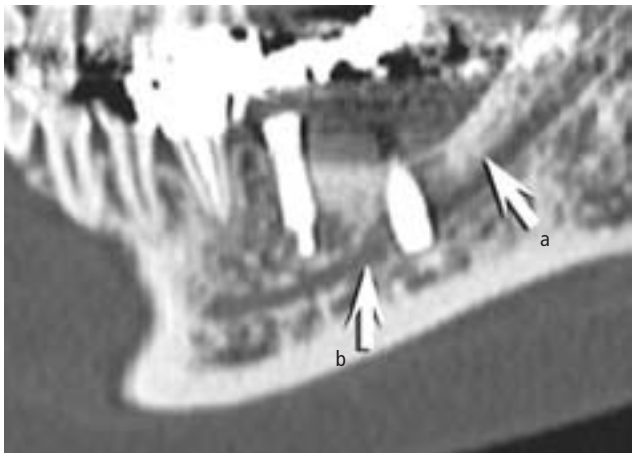


Fig. 24.3 The implant is completely through and inferior to the entire inferior alveolar nerve canal (IANC) diameter. (a) Superior, and (b) inferior cortical borders of the IANC.

Acts or omissions that may result in litigation

Inadequate training

Avoidable surgical complications and adverse outcomes have been linked to a lack of adequate surgical training and experience (8). Research linking high surgical volume to successful patient outcomes in high-complexity operations implies that low-volume, inexperienced surgeons are likely sources of error (9–11). Review of surgical errors suggests the inexperienced surgeon would benefit from specific interventions, such as mentoring and extended training. Clinicians who lack the training and experience to place or restore implants correctly, in conformance with the standards of reasonably careful care, have a legal obligation to refer patients to clinicians who are experienced and well trained in implant placement and restoration. All dentists placing and/or restoring implants are held to the same reasonable standards of care in the eyes of the law. Thus, all reasonably careful clinicians are required to possess and exercise a level of care consistent with current implant methodologies supported and substantiated by peer-reviewed literature. A two-day implant course is considered inadequate training for implant placement in close proximity to vital structures, compromised ridges or in the esthetic zones.

Unreasonable judgment in placing implants

Unreasonable judgment errors cannot be defended. Some examples of unreasonable judgment in placing implants follow:

- implant placement in areas of inadequate bone support because presurgical grafting was not done, resulting in implant failure, and/or sinus or nerve penetration (Fig. 24.4a, b)
- failure to obtain adequate presurgical imaging in order to avoid implant placement too close to vital structures, such as providing less than a 2 mm safety zone as the inferior alveolar nerve ascends before exiting at the mental foramen (Fig. 24.4c)
- extraction followed by immediate implant placement in a socket with insufficient bone remaining to stabilize the implant without encroaching on a vital anatomic structure (e.g. IANC, nasal or maxillary sinus)
- failure to assess and guide implant positioning in compromised anatomic areas, such an atrophic ridge, without pretreatment CAT or CBCT scan analysis
- implants contacting and damaging adjacent teeth
- placing poorly positioned implants because of judgment or surgical error (implants may be intentionally placed off-angle for ridge, bone, or restorative reasons) which leads to severely compromised esthetics, peri-implantitis, or compromised function.

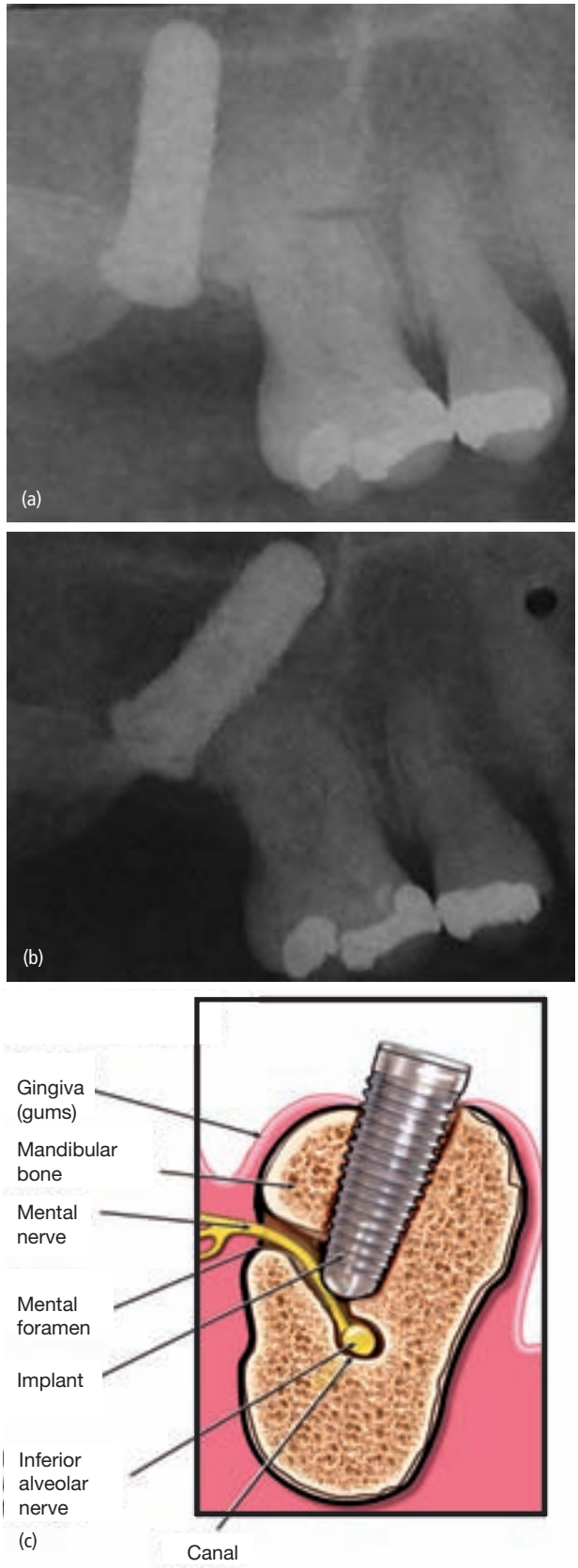


Fig. 24.4 (a, b) Implant placement in areas of inadequate bone support. (c) Diagram of implant penetrating the inferior alveolar nerve canal (IANC) as the inferior alveolar nerve ascends.

In one legal case which settled for $915 000 at mediation, an oral surgeon testified that he planned for a 2 mm safety zone for implant placement in the no. 20 region. However, the plaintiff patient contended the oral surgeon failed to align the no. 20 implant parallel to the adjacent natural tooth 21. Thus, the oral surgeon's off-angle implant placement resulted in the no. 20 implant "harpooning" over half the IANC diameter (Fig. 24.5d–f).

The oral surgeon's immediate postoperative Panorex (Fig. 24.5d) suggested IANC impingement, which was confirmed when the patient complained 8 hours postoperatively (and thereafter) of persistent numbness. A medical CT, 17 days after implant placement, confirmed IANC penetration (Fig. 24.5e). Three days later, the oral surgeon belatedly replaced the 9 mm implant with a 7 mm implant (Fig. 24.5g).

The patient also alleged that the oral surgeon had miscalculated the results of preimplant distraction osteogenesis surgery for treatment of the atrophic mandibular ridge. The oral surgeon testified that he believed that distraction osteogenesis had achieved a 4 mm vertical increase. However, the oral surgeon did not remeasure the purported gain just before implant placement. Retrospectively (looking through the retrospectoscope), no measurable augmentation gain could be demonstrated (Fig. 24.5a–c). Thus, the oral surgeon's attempt to gain ridge height to allow for a longer implant was unsuccessful.

Almost 3 years postoperatively the patient suffers anesthesia dolorosa with constant burning lip and chin pain. The patient is no longer able to work as a highly skilled accountant. The patient claimed that had the oral surgeon acted promptly at 8 hours postoperatively to back out the implant when the patient first reported persistent numbness, rather than delaying implant removal for 20 days, the resulting persisting dysesthesia and paresthesia would likely have been greatly reduced, if not entirely reversed.

Prevention of litigation

Standard of care definition

The standard of care requires a DPRI clinician to possess and use the level of skill, knowledge, and care in diagnosis and treatment that other reasonably careful DPRI clinicians should use in the same or similar circumstances (12). Standard of care definitions vary slightly from jurisdiction to jurisdiction, but all definitions focus on reasonable, prudent, and careful treatment as the benchmark standard.

Implantology is not an American Dental Association (ADA)-recognized specialty. Therefore, as stated previously, the standard of care is the generally same for all

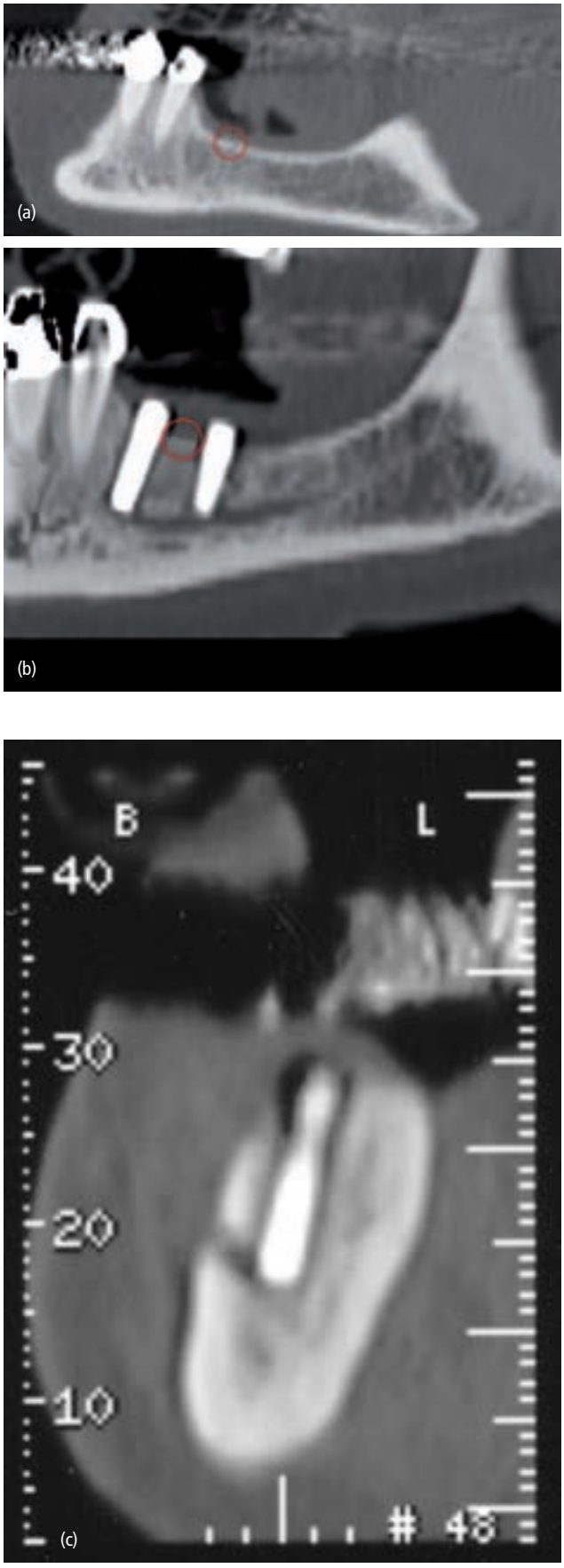


Fig. 24.5 (a) Predistraction osteogenesis (March 19, 2005). (b) Ridge area of distraction osteogenesis (June 7, 2005). (c) Postdistraction osteogenesis (April 3, 2006). (d) Immediate postoperative image showing implant no. 20 approximating the inferior alveolar nerve canal (IANC) and obscuring the area of the mental foramen (March 17, 2006). (e) Cone beam computed tomography (CBCT) of implant obscuring half of the IANC. (f) CBCT of implant obscuring half of the IANC.

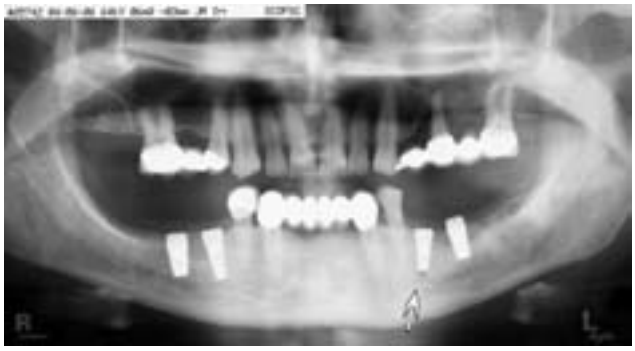


Fig. 24.5 ***(cont'd)*** (g) Replacement of the 9 mm implant with a 7 mm implant (April 6, 2006).

DPRI clinicians whether they are specialists or general practitioners, and whether they are surgically placing, removing, or restoring implants. Implants are often placed by specialists, i.e. oral surgeons and periodontists. However, all DPRI clinicians who place implants are held to the same standard of care under the law, since the necessary training, information, and technology are available to all.

The standard of care does not require perfection. Nor does it require ideal dentistry. Rather, the standard of care requires reasonably careful treatment, which is care based on scientific reason. Evidence-based research, as published in peer-reviewed journals, provides a scientifically reasoned basis for such reasonable care. The courts are cognizant of this fact (13).

Requirement to keep current

The standard of care requires DPRI clinicians to keep abreast of current research and continuing education courses. A DPRI clinician must re-evaluate practice modalities when new products or information emerge which challenge the safety and efficacy of existing products and techniques. A DPRI clinician should reasonably consider adopting or adapting to improved technologies, provided supporting research is scientifically valid, i.e. the research considers a statistically sufficient number of patients with adequate long-term evaluations of safety, efficacy, and durability. A prudent practitioner follows the maxim "Don't be the first nor the last" (to incorporate new technologies or products). Careful clinicians should also consider whether new implant systems which show clinical promise in short-term studies will deliver long-term success. Thus, do not make your office the manufacturer's clinical testing laboratory.

Alternative treatment choices

The standard of care recognizes that DPRI clinicians may differ in their treatment decisions. To comply with the standard of care, no one implant method is required exclusively. However, an alternative method choice must be a reasonable choice – even if it is a choice of the minority, rather than majority, of DPRI clinicians. For instance, there may be more than one reasonable choice for each of the following:

- grafting or membrane materials
- implant surface topography
- implant system
- immediate versus delayed implant placement, temporization, or loading
- grafting versus use of pink gingival masking materials.

Reasonable alternative methodologies do not encompass unreasonable choices. Thus, placing implants is an unreasonable choice if there is insufficient bone, including grafted bone, to place implants so as to avoid vital structure encroachment or penetration.

Informed consent

Bedrock principles of informed consent

The foundation of informed consent law holds that all persons of sound mind are entitled to do with their own bodies as they see fit (14). A layperson patient cannot make an intelligent informed choice of treatment unless the patient first receives adequate pretreatment information regarding alternatives, benefits, and potential complications. This is particularly true when a patient has no emergency needs, but rather has sufficient time to decide whether to undergo an elective treatment. Thus, the bedrock principles securing voluntary choice of treatment apply even more importantly to elective therapies such as teeth replacement with implants of lost or soon-to-be-lost teeth.

Negligent clinicians cause reasonably avoidable risks due to imprudence or carelessness. A patient cannot legally consent to negligent care (15). Thus, asking a patient to consent to negligent treatment risks is tantamount to requesting the patient to consent to a dental battery. (A battery is non-consensual touching of another person's body.) For example, extracting a full arch of periodontally healthy virgin teeth in a young patient – for the purpose of improving implant construction in healthy bone – is at least negligent and more likely the result of a fraudulently induced consent. A fraud claim for unnecessary treatment may subject the clinician to a claim for punitive damages. Professional liability insurance policies defend but do not indemnify fraud claims (16).

Definition of informed consent

Informed consent law requires the clinician, in advance of treatment, to inform the patient about all "material

facts and information" a reasonable patient would want to know in order to make an informed treatment choice.

The definition of what constitutes adequate informed consent varies somewhat between states, as well as between countries. However, the definitions represent variations of the requirement to disclose all "material information" the reasonable patient would want to know in choosing the implant option. Not informing patients of reasonable treatment alternatives as well as potential complications violates the doctrine of informed consent in all states. In some states, expert testimony is not needed to determine what a reasonable patient should be told. In other states, expert testimony is required.

What should be disclosed

Adequate informed consent requires that a patient be informed of the ABCs – the alternatives, benefits, and complications – of proposed treatment, along with the pros and cons of alternative therapies or options (17). A patient has a right to be informed of these ABCs by the treating clinician, and not solely from an informed consent form or by a front office staff person who lacks a dental license.

Informed consent must be presented in layperson's language, so that the patient can appreciate and understand what the treatment risks are. The patient must also be told of the consequences of doing nothing. Ultimately, it is the patient's decision to proceed or not with proposed treatment. Although the doctor knows best and may so recommend, the best interest of the patient requires that the patient make the final decision to proceed or not with treatment after being fully informed of the alternatives, benefits, and risks.

For example, when the patient has a choice between an implant and a three-unit fixed bridge to replace a missing tooth, the patient should be informed of implant benefits such as preserving alveolar bone, and avoiding the reduction of the sound tooth structure of adjacent abutment teeth, with the associated risk of endodontics and/or future crown marginal caries associated with a three-unit bridge. The patient should also be informed about an implant's principal complications, i.e. those associated with most surgeries, including infection or failure. However, other risks specifically associated with implants, i.e. implant fracture, malposition, sinus perforation, risk of sensory changes, and a compromised esthetic result must also be included as part of the informed consent discussion.

Certain treatment decisions are matters of clinician choices in which the patient lacks significant training or knowledge to provide informed consent for various treatment modalities. Choices in implant design or application require the clinician's sound clinical judgment. Clinical judgment – rather than patient decisions – is appropriate in the following circumstances:

- whether or not to splint implant restorations to reduce occlusal stress
- implant position, implant staging (one- or two-stage implants), and use of special techniques such as augmentation procedures before and/or in conjunction with implant placement
- selection of implant length and width, and angulation of implant placement
- type of provisional, fixed, or removable restoration where necessary to avoid transmucosal loading.

Patient educational materials – whether written, illustrations, or videos – aid adequate informed consent since implant subject matter is technical and must be explained in lay terms. Staff review of consent forms and patient educational materials supplement, but do not supplant the treating dentist's legal obligation to advise the patient, and then answer any patient informed consent questions following the informed consent discussion. Appendix 1 presents an example of an informed consent form. Professional organizations offering informed consent forms include the International Congress of Oral Implantologists, American Academy of Periodontology, and American Association of Oral and Maxillofacial Surgeons.

Informed consent defense applies only to procedures performed within the standard of care

If a treatment failure results from substandard care, a clinician cannot legally or justifiably defend the failure by claiming that the patient was told of the risk of failure before treatment. Thus, for example, if the clinician overextends an implant or drill, penetrating the IANC and causing nerve injury, the clinician cannot defend negligent implant drilling or placement by claiming that he or she presurgically informed the patient that injury to the inferior alveolar nerve was a risk of the implant surgery. Three-dimensional imaging, an accurate surgical guide, and a 2 mm safety zone between the superior crestal IANC border and the deepest implant drilling can reasonably avoid this risk.

An informed consent defense applies only to treatment that is performed within the standard of care. If the clinician is reasonably careful during treatment, but an untoward result occurs, the DPRI clinician is not liable if the patient was forewarned of the potential risk before treatment, and the patient elected to proceed with treatment with such informed knowledge.

A reasonably unavoidable risk which manifests during treatment represents a maloccurrence and not malpractice. For example, a small percentage of implants fail for non-negligent reasons. Notwithstanding the clinician's

legal non-culpability, he or she should be sensitive to the patient's feelings of disappointment. When an implant fails, regardless of the cause, it is a 100% failure rate for the patient.

Informed consent should be regarded as a process rather than a signature on a form. This process includes ongoing shared information and developing choices. Communication is necessary if informed consent is to be realized. It is not intended primarily as a clinician's safeguard against liability. Nor is it meant to provide a patient's unlimited demand for treatment or choice of treatment modalities that are clinically inadvisable. Respecting the patient's autonomy means that the clinician cannot impose treatments. It does not mean that the clinician must provide or offer a choice of inappropriate, unreasonable, or harmful treatment (18).

Dental implants are a recognized and well-accepted treatment option for tooth replacement (19–21). The standard of care requires that the implant option be offered as one of the reasonable alternatives for tooth replacement. The legal doctrine of informed consent requires that a patient is entitled to be informed of all reasonable therapeutic alternatives, including implants, removable or fixed bridges, and non-replacement.

Informed refusal

Informed refusal is a medicolegal concept whereby a patient gives refusal based on an understanding of the facts and of the implications of not following a recommended diagnostic or therapeutic action. Informed refusal is linked to the informed consent process. Just as a patient has a right to give consent, a patient also may choose to refuse consent. However, in order to have adequate informed refusal, the patient needs to be provided with the relevant facts.

The concept of informed refusal is similar to that of informed consent. Thus, the patient has the right to be informed of the risks of refusing a particular treatment. It is not enough simply to document that the patient refused a recommendation for implant treatment. Also document efforts to explain to the patient the risks of refusing implant treatment such as a less stable denture and progressive bone atrophy underneath a completely tissue-borne denture. The American Academy of Periodontology offers an informed refusal form (http://www.perio.org/members/pm/forms/index.htm).

Record-keeping requirements

The most effective litigation-preventive measure is to be careful and caring in treating patients. However, if sued, the dentist's best defense, assuming the absence of negligent treatment, is to have maintained accurate, complete, and contemporaneous records.

A clinician's credibility in any legal proceeding can be bolstered by thorough documentation. Conversely, credibility is undermined by a lack of adequate documentation. It is critical to make chart entries contemporaneously to the treatment event. Belated charting should be clearly distinguished by indicating the date and time of the belated entry.

Spoliation of evidence is defined as the failure to preserve property for another's use as evidence in pending or future litigation. Spoliation may include the alteration or fabrication of evidence such as falsified dental records or radiographs to support a defense or claim. If evidence of a defendant clinician's altered, falsified records is admitted as trial evidence, the jury will be instructed that they may disbelieve the entirety of the defendant's testimony and consider that record falsification was done as consciousness of guilt (22).

Computer *axial* tomograph or cone-beam computed tomographic imaging

CBCT or CAT imaging aids treatment planning and guides implant placement (23, 24). Most importantly, a CT scan identifies with greater precision the location of vital structures such as the IANC as it courses through the mandible and ascends before exiting at the mental foramen. Correctly locating vital anatomic structures, such as the IANC to avoid inferior alveolar nerve damage or mandibular concavities to avoid lingual artery perforations, is a primary advantage of CBCT and CAT compared with two-dimensional plain film. Penetration or harpooning of the inferior alveolar nerve is a frequent genesis of implant negligence lawsuits in this author's experience (Figs 24.3, 24.5c).

The preoperative CT scan can help determine the distance from the alveolar ridge to the IANC, including diagnosing bifid canals (25). Intraoperative periodic periapical radiographs during the drilling sequence have been suggested but lack the accuracy of CAT or CBCT images (26).

Avoiding inferior alveolar nerve injury

Preoperative radiographic evaluation of the implant site is necessary both for treatment planning and to prevent harpooning of the neurosensory inferior alveolar nerve bundle (26–28) (Fig. 24.3).

As a reasonable precaution, a safety zone of 2 mm between the end of the implant and implant drilling and the IANC is recommended. Clinicians have recommended this 2 mm safety zone precaution for over a quarter of

a century (28–33). CAT, CBCT imaging, and surgical guides help keep the safety zone inviolate and avoid the IANC danger zone.

Implant drill depth burs vary, depending on the manufacturers' recommendations. In some cases, manufacturers recommended drilling deeper than the depth to which the implant will be placed. For example, Nobel Biocare warns: "Caution. Implant drill burs are 1 mm longer than the implant." A clinician is obligated to recognize and comply with such manufacturers' precautions.

If a nerve injury is suspected neurosensory testing should document the nature of the altered sensation including duration, inducing factors, hyperesthesia, hypoesthesia, and dysesthesia. Clinicians should perform a thorough neurosensory examination and document the results if numbness persists the day after surgery when the effects of the local anesthetic should have worn off. Accordingly, the postimplant postoperative written instruction form should state:

> "Call our office immediately if lip and/or chin numbness persists the next morning following implant surgery. An implant contacting the underlying jaw nerve requires prompt removal or backing out to avoid permanently damaging the underlying sensory jaw nerve."

The goal of early referral to a microsurgeon is to minimize distal degeneration of the nerve. Prompt microsurgical repair avoids wallerian degeneration of the distal portion of a traumatically injured inferior alveolar nerve. If nerve injury symptoms persist after implant removal (see below), the clinician must inform the patient of the existence of nerve injury and make an immediate referral to a microneurosurgeon for evaluation and/or microsurgical repair. Time is of the essence (34).

If an implant is potentially violating the IANC or sinus, the clinician should either (i) decrease implant depth by unscrewing the implant a few turns to leave the implant short of the IANC or sinus membrane, or (ii) remove the implant entirely. Although CBCT or CAT images are recommended, even if such imaging is reasonably available on a stat (urgent) basis, the clinician should not delay backing out or removing a suspect implant even without imaging that confirms implant penetration into vital structures. After backing out or removing the implant, the clinician can obtain CBCT or CAT images to verify whether the implant actually penetrated the IANC or sinus, and, if so, how much. However, when the patient has had persistent neuropathic symptoms since implant placement, this stat adage pertains: "When in doubt, back it out." A later CBCT or CAT reading before bony healing of the drill site, which confirms the previously removed implant and/or drill position, can guide the clinician on where or whether to reposition a new implant (35).

Litigation risk management

Refunds

If a displeased patient declines a refund or referral, the clinician may wish to ask the patient what they are seeking. The clinician should inform the clinician's insurance carrier and follow the carrier's instructions for negotiating with the patient. However, the carrier may wish to negotiate directly with the patient rather than negotiate through the dentist. If a settlement can be mutually achieved, the patient should be requested to sign a release, stating that he or she accepts the settlement funds as a full and final out-of-court settlement, and agrees not to sue (see Appendix 2).

Invalidity of lawsuit waivers

It is contrary to public policy to have a patient sign a document waiving the patient's legal right to sue for compensation in a lawsuit claiming negligent dental treatment. Such waivers are the equivalent of requesting a patient to waive not only the patient's constitutional right to a jury trial, but also the patient's right to the dentist's fiduciary obligation always to protect and preserve the patient's best interest. Such waivers are voidable, i.e. legally unenforceable (15). Otherwise, no healthcare practitioner could ever be sued, since every healthcare practitioner would require patients to sign waivers of the right to sue.

A patient cannot legally consent to negligent implant surgery or a negligently placed implant prosthesis. Thus, requesting the patient's consent for treatment which the clinician knows or should know violates the standard of care, is invalid.

Admitting errors

A frequent genesis of patient lawsuits against dentists is the patient's feeling of betrayal. Most patients trust their clinicians, and thus feel betrayed if the clinician injures them and subsequently conceals from the patient what happened. However, conveying compassionate concern about a poor outcome not only improves the clinician's relationship with the patient but also reduces the likelihood of a lawsuit. If an adverse or untoward event (incident) occurs, inform the patient what occurred and either provide for corrective treatment or offer referral for diagnosis and corrective care. File an FDA MedWatch report to alert the FDA and implant manufacturer of

complications and/or inadequate labeling or directions for use. A copy need not be provided to the patient. The patient's name may be omitted from the MedWatch report to preserve patient confidentiality.

Take-home hints

- Providing a patient with adequate informed consent helps protect the dentist placing or restoring implant (DPRI) clinician against lawsuits for the occasional, unavoidable, non-negligent treatment risks, but does not protect against negligent treatment errors resulting from deviations of prudent practice. A patient cannot legally waive their right to sue for negligence by signing a "waiver to sue" form, as this would violate public policy. Such forms are voidable and legally unenforceable.
- Patients have the right to refuse recommended and preferred treatment, including implants, and may choose instead less desirable therapy, provided all reasonable treatment options were disclosed to the patient with the pros and cons of each alternative therapy. This should be clearly documented on the patient's chart.
- If only one cortical border of the IANC is visible on a Panorex or periapical film (instead of two borders), presume that the visible cortical border is the inferior border, which it almost invariably is, rather than the superior border. "Harpooning" of the inferior alveolar nerve with the implant drill or implant is an avoidable complication which often results from mismeasurement if the surgeon incorrectly assumes that the sole visible cortical border is the superior border.
- To err on the side of caution, a 2 mm safety zone between the implant, implant drill depth, and the IANC is recommended. This precaution has been recommended for more than a quarter of a century.
- CBCT 3D imaging should be considered for routine use for implant placement to aid prosthetic alignment and avoid permanent injury to adjacent vital structures, particularly the inferior alveolar nerve. A medical CT offers similar advantages for implant treatment planning or postoperative evaluation, but entails increased radiation exposure (Table 24.1) (36).
- A patient's postoperative instruction sheet should state that if numbness persists the morning following mandibular posterior implant surgery, the implant surgeon should be notified immediately. The surgeon should examine the patient as soon as possible. To prevent permanent inferior alveolar nerve injury, backing or taking out the implant is a precaution in instances of paresthesia persisting the next day following implant surgery until a stat CBCT or CAT and radiologist's report is obtained to confirm or rule out IANC penetration. When in doubt, back it out.
- The FDA's MedWatch program relies on clinicians' voluntary confidential reporting of adverse incidents. Only if the FDA receives a sufficient number of similar adverse incidents will it likely investigate whether an implant is being properly manufactured or contains adequate precautions or warnings on its label.

Table 24.1 Comparisons of doses with various cone beam computed tomography (CBCT) machines (36)

CBCT unit	FOV (cm)	Total dose (μSv)
Accuitomo	(4 × 4)	20.02
Accuitomo	(6 × 6)	43.27
i-CAT	23	104.5
i-CAT	30.5	193.4
NewTom	30.5	58.9
Medical CT	Maxilla and mandible	2100

FOV: field of view.

References

1. Frankel D. What determines malpractice payments? *MedMal Reporter* 2007; **I**(1): 1.
2. Odom L, Garcia A, Milburn P. The ethnicity of capping non-economic damages to control rising healthcare costs: panacea or false and misleading practice? *Internet J Healthcare Admin* 2005; **3**(1).
3. Beidser P. *Limiting tort liability for medical malpractice*. Washington DC: Congressional Budget Office (CBO); 2004.
4. Quintanilla R. Family of woman who died in dental chair gets $3.9 million. *Chicago Tribune*, August 13, 2008.
5. *Kallestad v. Collins*. Dentist's patient awarded millions: jury rules oral surgeon performed negligently. *Spokesman Review*, August 27, 2008.
6. *Keller v. Flugrad* (2009) Superior Court of New Jersey, Law Division, Middlesex County, Docket No. MID-L-5140-06.
7. Baxter C. Malpractice survey: a survey of 242 dental negligence cases. www.experts.com, 2008.
8. Albrektsson T. Is surgical skill more important for implant success than changes in implant hardware? *Clin Implant Dent Relat Res* 2001; **3**: 174–5.
9. Evans A, Leeson R, Newton JT, Petrie A. Are oral surgeons as good as they think they are? *Br Dent J* 2005; **198**: 765–9.

10. Regenbogen S, Greenberg CC, Studdert D, Lipsitz S, Zinner M, Gawande. Patterns of technical error among surgical malpractice claims: an analysis of strategies to prevent injury to surgical patients. *Ann Surg* 2007; **246**: 705–11.
11. Regenbogen SE, Ehrenfeld JM, Lipsitz SR, Greenberg CC, Hutter MM, Gawande AA. Utility of the surgical Apgar score: validation in 4119 patients. *Arch Surg* 2009; **144**: 30–6.
12. California Civil Jury Instruction 501 (Spring 2010). See also Liability of Physicians and other Medical Practitioners, Section 31.11 (Bender M).
13. Federal Judicial Center. *Reference manual on scientific evidence*, 2nd edn, 2000.
14. *Cobbs v. Grant* (1972) 8 Cal 3d 229, 242.
15. *Tunkl v. Regents of University of California* (1963) 60 Cal 2d 92.
16. California Insurance Code 533.
17. Sfikas P. A duty to disclose. *J Am Dent Assoc* 2003; **134**: 1329–33.
18. Mathews SC, Pronovost PJ. Physician autonomy and informed decision making. *JAMA* 2008; **300**: 2913–15.
19. American Dental Association Council on Scientific Affairs. Dental endosseous implants: an update. *J Am Dent Assoc* 2004; **135**: 92–7.
20. Ganz S. Defining new paradigms for assessment of implant receptor sites. *Compendium* 2008; **29**: 256.
21. Torabinejad M, Lozada J, Puterman I, White S. Endodontic therapy or single tooth implant? A systemic review. *J Calif Dent Assoc* 2008; **36**: 429–37.
22. *Thor v. Boska* (1974) 38 Cal.App.3RD, 558–69.
23. Bjerklin K, Ericson S. How a computerized tomography examination changed the treatment plans of 80 children with retained and ectopically positioned maxillary canines. *Angle Orthod* 2006; **76**: 43–51.
24. Guerrero ME, Jacobs R, Loubele M. State-of the-art on cone beam CT imaging for preoperative planning of implant placement. *Clin Oral Invest* 2006; **10**: 1–7.
25. Rouse P, Nancy J, Bar D. Identification of double mandibular canals: literature review and three case reports with CT scans and cone beam CT. *Dentomaxillofac Radiol* 2007; **36**: 34–8.
26. Burstein J, Mastin C, Le Bach. Avoiding injury to the inferior alveolar nerve by routine use of intraoperative radiographs during implant placement. *J Oral Implantol* 2008; **34**: 34–8.
27. Delcanho RE. Neuropathic implications of prosthodontic treatment. *J Prosthet Dent* 1995; **73**: 146–52.
28. Worthington P. Injury to the inferior alveolar nerve during implant placement: a formula for protection of the patient and clinician. *Int J Oral Maxillofac Implants* 2004; **19**: 731–4.
29. Greenstein G, Cavallaro J, Romanos G, Tarnow D. Clinical recommendations for avoiding and managing surgical complications associated with implant dentistry: a review. *J Periodontol* 2008; **79**: 1317–29.
30. Greenstein G, Tarnow D. The mental foramen and nerve: clinical and anatomical factors related to dental implant placement. A literature review. *J Periodontol* 2006; **77**: 1933–43.
31. Kraut R, Chahal O. Management of patients with trigeminal nerve injuries after mandibular implant placement. *J Am Dent Assoc* 2002; **133**: 1351.
32. Misch CE. *Contemporary Implant Dentistry*, 3rd edn. St Louis, MO: Mosby Elsevier; 2008: 703–4.
33. Misch CE, Crawford EA. Predictable mandibular nerve location: a clinical zone of safety. *Int J Oral Implantol* 1990; **7**: 37–40.
34. Pogrel MA. Damage to the inferior alveolar nerve as the result of root canal therapy. *J Am Dent Assoc* 2007; **138**: 65–9.
35. Zinman EJ, White SC, Tetradis S. Legal considerations in the use of cone beam computer tomography imaging. *CDA Journal* 2010; Jan. 49–56.
36. Ludlow J, Davies-Ludlow L, Brooks S, Howerton B. Dosimetry of 3 CBCT devices for oral and maxillofacial radiology: CB Mercuray, NewTom 3G and i-CAT. *Dentomaxillofac Radiol* 2006; **35**: 219–26.

Appendix 1: International Congress of Oral Implantologists consent form. (Reproduced with permission from the ICOI. Forms can be purchased at www.icoi.org.)

The International Congress of Oral Implantologists

IMPLANT PATIENT INFORMATION AND CONSENT FORM

1. I have been informed and I understand the purpose and the nature of the implant surgery procedure. I understand what is necessary to accomplish the placement of the implant under the gum or in the bone.

2. My doctor has carefully examined my mouth. Alternatives to this treatment have been explained. I have tried or considered these methods, but I desire an implant to help secure the replaced missing teeth.

3. I have further been informed of the possible risks and complications involved with surgery, drugs, and anesthesia. Such complications include pain, swelling, infection and discoloration. Numbness of the lip, tongue, chin, cheek, or teeth may occur. The exact duration may not be determinable and may be irreversible. Also possible are inflammation of a vein, injury to teeth present, bone fractures, sinus penetration, delayed healing, allergic reactions to drugs or medications used, etc.

4. I understand that if nothing is done, any of the following could occur: bone disease, loss of bone, gum tissue inflammation, infection, sensitivity, looseness of teeth, followed by necessity of extraction. Also possible are temporomandibular joint (jaw) problems, headaches, referred pains to the back of the neck and facial muscles, and tired muscles when chewing.

5. My doctor has explained that there is no method to accurately predict the gum and the bone healing capabilities in each patient following the placement of the implant.

6. It has been explained that in some instances implants fail and must be removed. I have been informed and understand that the practice of dentistry is not an exact science; no guarantees or assurance as to the outcome of results of treatment or surgery can be made.

7. I understand that excessive smoking, alcohol, or sugar may effect gum healing and may limit the success of the implant. I agree to follow my doctor's home care instructions. I agree to report to my doctor for regular examinations as instructed.

8. I agree to the type of anesthesia, depending on the choice of the doctor. I agree not to operate a motor vehicle or hazardous device for at least 24 hours or more until fully recovered from the effects of the anesthesia or drugs given for my care.

9. To my knowledge I have given an accurate report of my physical and mental health history. I have also reported any prior allergic or unusual reactions to drugs, food, insect bites, anesthetics, pollens, dust, blood or body diseases, gum or skin reactions, abnormal bleeding or any other conditions related to my health.

10. I consent to photography, filming, recording, and x-rays of the procedure to be performed for the advancement of implant dentistry, provided my identity is not revealed.

11. I request and authorize medical/dental services for me, including implants and other surgery. I fully understand that during, and following the contemplated procedure, surgery, or treatment, conditions may become apparent which warrant, in the judgment of the doctor, additional or alternative treatment pertinent to the success of comprehensive treatment. I also approve any modification in design, materials, or care, if it is felt this is for my best interest.

_____ Signature of Doctor

_____ Signature of Patient

If the patient is unable to sign or is a minor (signature of parent or legal guardian)

_____ Witness

Appendix 2: Release of liability form

R E L E A S E

1. FOR AND IN CONSIDERATION of a refund of _____ Dollars ($_____.___), _____ (insert patient's name) does hereby forever release and discharge _____(insert dentist's name), his/her agents, staff, and employees from any alleged claim of negligence, malpractice, improper treatment or billing errors.

2. There is a risk that subsequent to the execution of this Release, the undersigned patient _____(insert patient's name) will incur or suffer personal or bodily discomfort, loss, damage, injury, or any of these which are in some way caused by dental care or treatment at the offices of _____(insert dentist's name), but which are unknown and unanticipated at the time this Release is signed; and further there is a risk that damages presently known may be or may become more serious than the undersigned now expects or anticipates.

3. The undersigned patient shall assume the above-mentioned risks and this Release shall apply to all unknown or unanticipated results of the occurrence described above as well as those known and anticipated.

4. This Release is the result of a compromise and shall never at any time for any purpose be considered as an admission of liability or responsibility on the part of _____(insert dentist's name), who continues to deny such liability and to disclaim such responsibility but is agreeing to a refund at patient's request and to resolve any and all outstanding disputes patient may have.

I, the undersigned patient, have read the foregoing Release and acknowledge my understanding and agreement of the contents thereof.

DATED:_____

_____
(Patient's signature)

_____
(Witness)

Chapter 25

Management of implant complications by the experts

Introduction

This chapter presents ten case reports authored by 11 expert clinicians demonstrating different approaches to the treatment of various implant complications in patients who presented to their private offices. The etiology, prevention, and treatment of these complications are reviewed in each of the case reports. However, a more complete discussion of each problem can be found in previous chapters.

The cases are presented according to whether or not the implant was retained and treated or removed and replaced with a new implant(s) and restoration. In all but one case, the complications are in the esthetic zone (maxillary anterior area). Treatment of the cases varies from retention of the implant and treatment with soft-tissue grafts to removal of the implant(s), followed by hard- and soft-tissue augmentation before and in conjunction with new implant placement.

The first three cases involve the former approach, where the treatment involved salvaging the implant and using soft-tissue grafting procedures to correct or submerge the implants. The next two cases involve complications of bone loss around an immediately placed implant and one placed in a patient with a compromised systemic condition in a compromised site. The next case involves treatment of the sequelae of a failed implant before placement of a new one. The last four cases involve complications arising from severe implant malposition of integrated implants requiring implant removal, augmentation procedures, and new implant placement with new final restorations. Each of these cases can be used as a treatment guide for similar complications that present to a clinician's office.

Cases

Case 1: Treatment of midbuccal recession in the esthetic zone

Pamela K. McClain DDS

A healthy 32-year-old female presented to our periodontal office with a chief complaint of soft-tissue recession of the implant in the no. 9 position (Fig. 1). The fixture had been uncovered and a healing abutment had been placed 6 weeks before evaluation. Examination revealed a 4 mm recession defect with limited (1 mm) keratinized tissue over the buccal aspect of the fixture (Figs 2, 3). The inter-

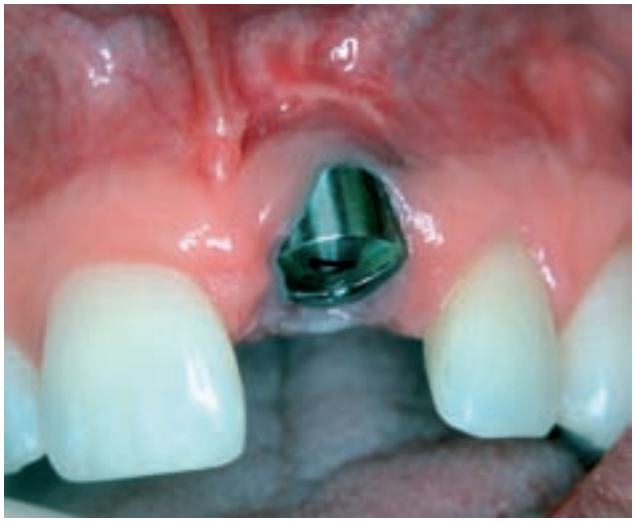


Fig. 1 Appearance of the patient at the time of initial examination, 6 weeks after implant exposure and abutment placement.

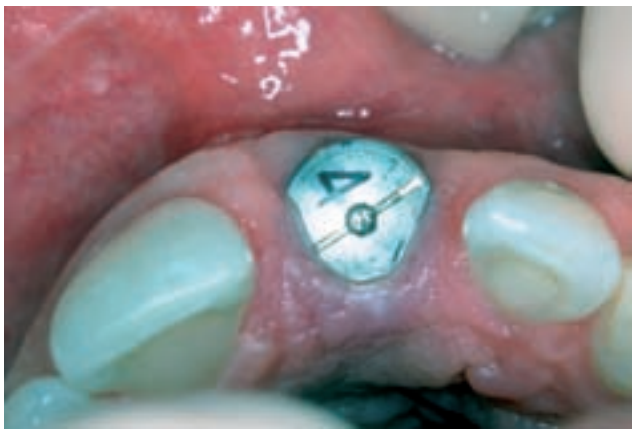


Fig. 2 Occlusal view of the implant at the time of examination.

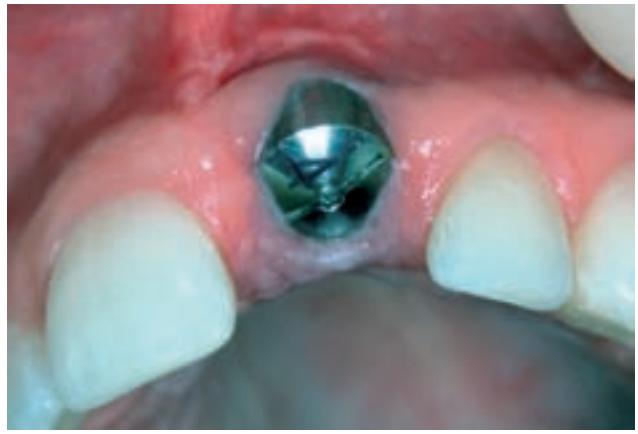


Fig. 3 Buccal/occlusal view at the time of examination showing limited keratinized tissue.

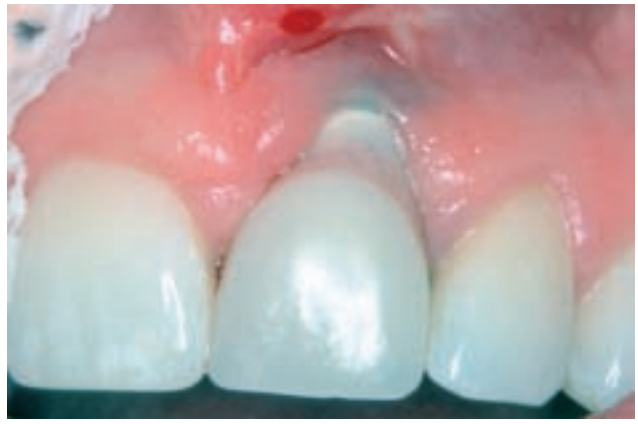


Fig. 4 Appearance at the time of surgery after the provisional crown had been placed.

proximal soft tissue and bone were in a favorable position.

Etiology

The etiology of this complication was related to poor implant positioning (buccoversion) combined with a reduced band of keratinized tissue (compared to adjacent teeth) probably caused by the surgical flap incision design during implant placement. Prevention of this midbuccal recession on a single implant would include proper incision design, i.e. midcrestal or lingual to the crest, proper facial lingual implant placement, with the implant emerging toward the cingulum, and use of a smaller diameter implant if necessary to avoid contact with the buccal plate (see Chapters 8 and 11).

In cases where there is a limited band of buccal keratinized tissues, a connective tissue graft performed before implant placement to augment this tissue would be indicated. Apical positioning of the keratinized gingiva during implant placement is another technique to avoid this complication.

Treatment

Surgical intervention using a connective tissue graft was planned; however, the patient had a provisional crown placed before surgery (Fig. 4). Intrasulcular incisions retaining the periosteum on the buccal plate of bone were made from teeth nos 8–10 leaving the papillae intact (Fig. 5). A subepithelial connective tissue graft was obtained from the palate and a tunnel procedure was employed, using the suture to pull the graft through the flap (Fig. 6). The graft was secured with a 5-0 chromic gut P-3 suture (Ethicon JJ 634G) (Fig. 7). Six weeks after surgery minimal improvement was observed (Fig. 8) and a second graft procedure was planned. Although the plan included removal of the provisional and placement of a cover screw, the patient refused and agreed to accept a compromised result or minimal improvement. Two

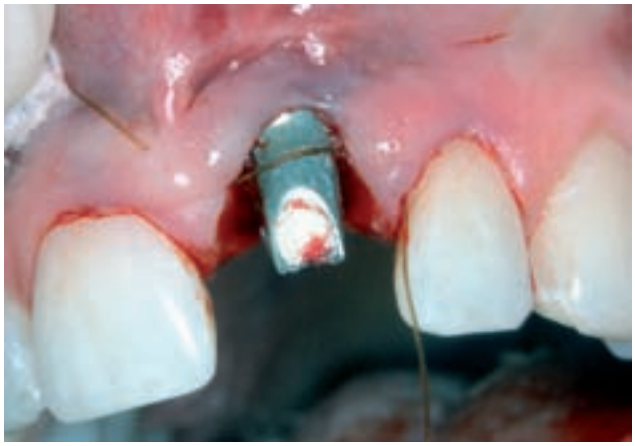


Fig. 5 Suture placed to facilitate graft placement with a tunnel procedure.

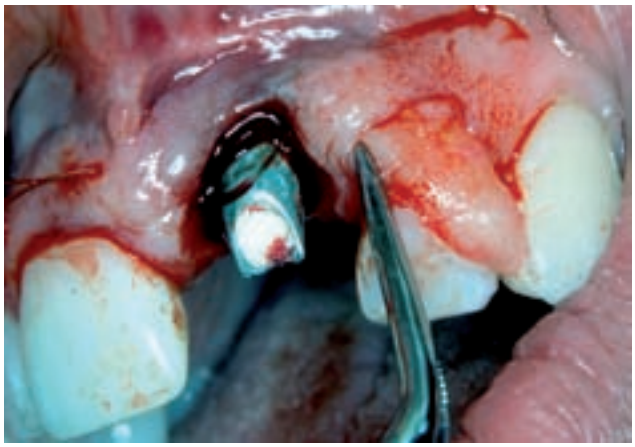


Fig. 6 Graft being positioned into the recipient site through the tunnel.

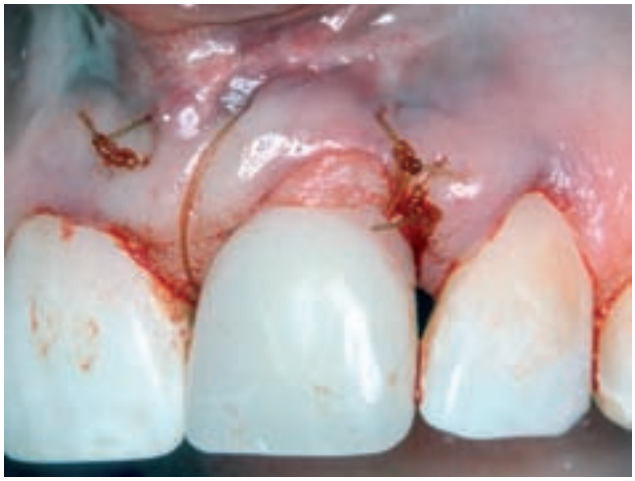


Fig. 7 Graft secured with a horizontal mattress suture.

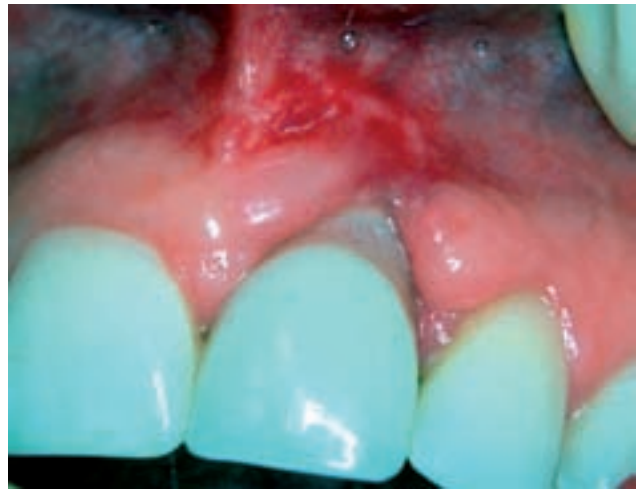


Fig. 8 Appearance of the graft 6 weeks after first surgery.

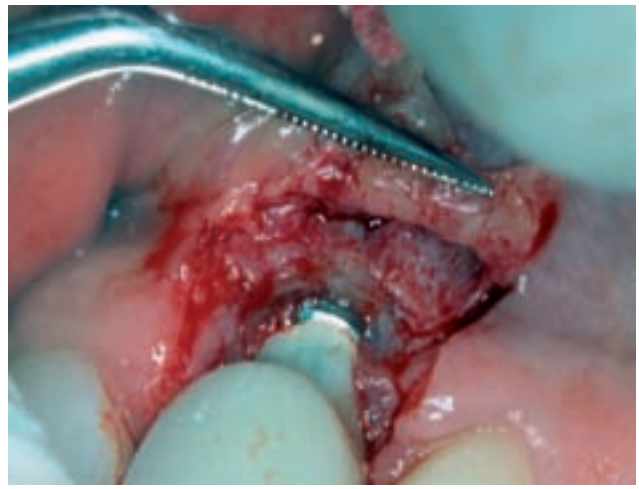


Fig. 9 Vertical releasing incisions and partial-thickness flap at second stage surgery 8 weeks after initial surgery.

months after the first surgical procedure, a second surgery was performed. A partial-thickness flap was made with vertical incisions on the mesial and distal aspects of the implant retaining the interproximal papillae (Fig. 9). In addition, the provisional was modified to create a concave contour to allow better tissue adaptation. A subepithelial connective tissue graft from the palate was placed on the buccal aspect of the implant and sutured with 5-0 chromic gut suture with a P-3 needle (Fig. 10). The flap was coronally positioned and secured with the same suture (Fig. 11). Healing was uneventful and at 19 months considerable improvement was observed (Fig. 12). Given the limitations of maintaining a fixed provisional, the current case demonstrates treatment of facial soft-tissue recession related to an implant that was placed too far buccally.

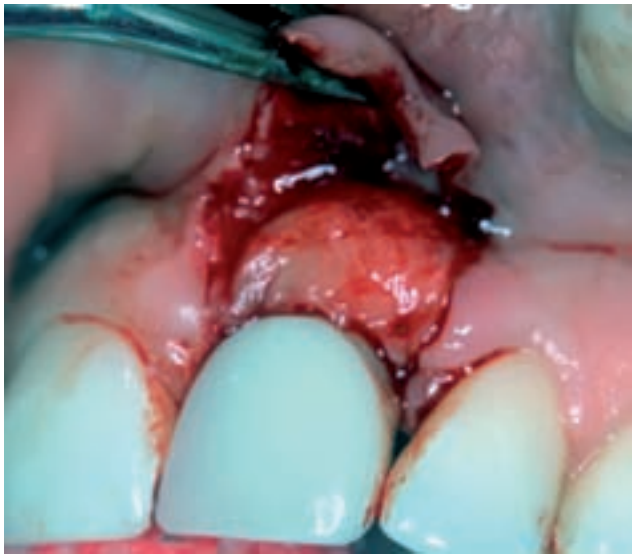


Fig. 10 Placement of subepithelial connective tissue graft and securing with 5-0 chromic gut suture.

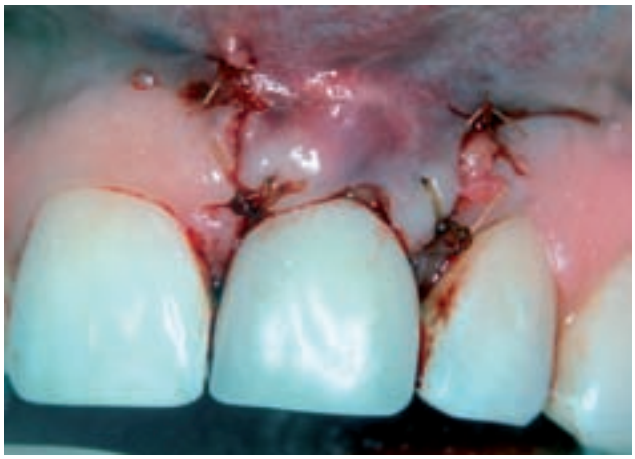


Fig. 11 Coronal advancement and suturing of the flap.

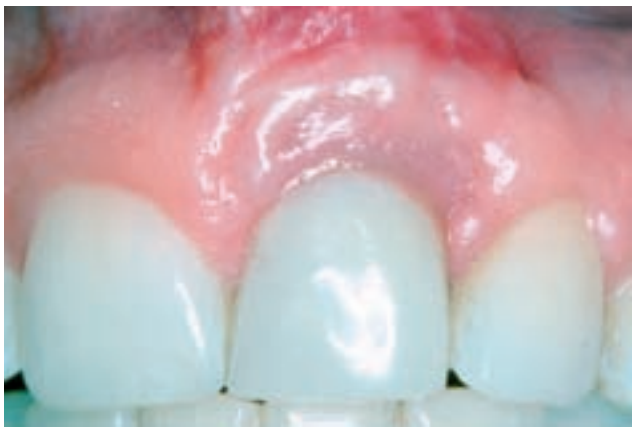


Fig. 12 Nineteen-month postoperative appearance after second surgery.

Case 2: Treatment of buccal soft-tissue recession on a restored central incisor implant

Jeffrey R. Lemler DDS

A healthy 29-year-old male Caucasian presented with a chief complaint of progressive recession on the facial of an implant restoration (Fig. 1). The crowns had been placed on the maxillary central incisor implants approximately 3.5 years earlier. The area of issue was the facial aspect of the left central implant. Owing to the low smile line, the patient's complaint was not esthetic but a concern over long-term health and stability. The implants were externally hexed and placed as immediates with a flapless approach but were not loaded immediately. A fixed bonded provisional was used, so no premature loading was present. There were no reported complications associated with the extractions, implant placement, or restoration. The crowns were screw retained; therefore, presence of excess cement could not have contributed to the defect.

Upon clinical and radiographic examination the implants appeared to be well positioned and osseointegrated. There was no apparent loss of bone noted proximal to the implants. This assessment was determined by comparing X-rays taken at the time of original case completion to X-rays taken at the present consultation (Fig. 2a, 2b). Radiographs, however, were not calibrated. Crown contours were within normal limits. There was a reduced papilla between the implant crowns. Plaque levels throughout the mouth were good, and minimal inflammation was noted. There were no significant probing depths or bleeding on probing associated with the implants (Fig. 3). The occlusion was within normal limits with no prematurities or indications of bruxism.

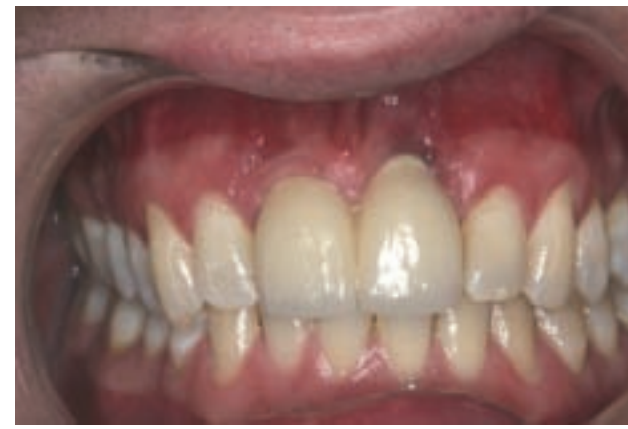


Fig. 1 Progressive recession facial to no. 9 implant (3.5 years after restoration).

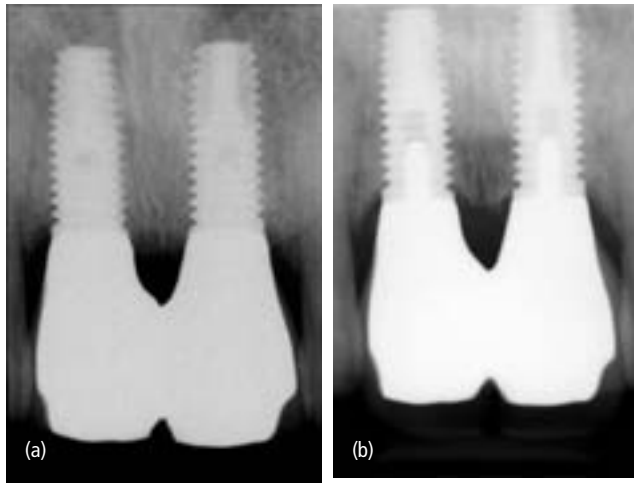


Fig. 2 (a) Periapical radiograph taken immediately after completion of prosthetics. (b) Periapical radiograph taken 3.5 years later, at time of referral.

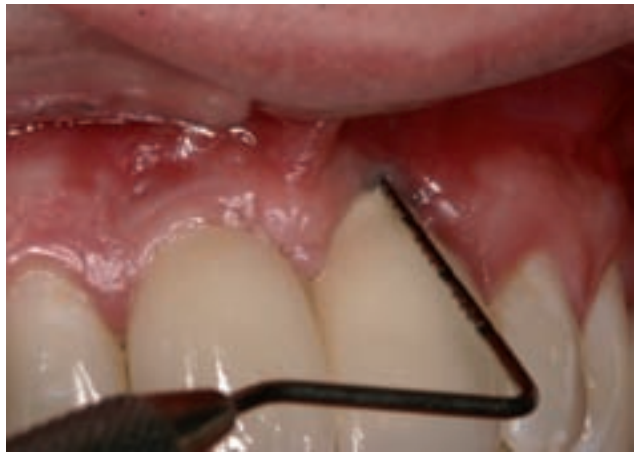


Fig. 3 No significant probing or inflammation associated with defect.

Etiology

Based on a comparison of a photograph taken at the time of completion of the restoration with one taken at the present consultation, it appeared that approximately 3 mm of recession had occurred on the facial aspect of the left central implant with loss of the keratinized gingiva. From a proximal view, loss of soft-tissue thickness was also noted (Fig. 4). Since plaque, prosthetic contours, occlusion, and residual cement had been eliminated as etiologic factors, it was surmised that there was probably an inadequate width of buccal alveolar bone at the time of implant placement. Furthermore, it was noted that in normal healing, additional resorption of the alveolar plate had probably occurred, resulting in diminished blood supply to the overlying gingiva and the ensuing recession.

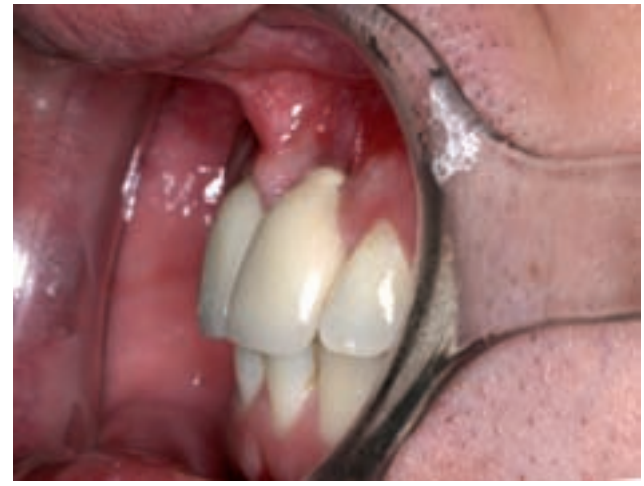


Fig. 4 Proximal view of buccal ridge defect.

Prevention

In recent years there has been an emphasis on decreasing the time required for restorative implant reconstruction and simplifying procedures. As a result, concepts such as immediate placement, immediate load, and flapless surgery were developed. However, these procedures are not without potential complications or limitations. When implants are placed adjacent to a buccal plate of bone less then 2 mm thick, the bone has been reported to recede (1). The overlying soft tissue supported by this bone will also recede (2). Placement of implants in such sites will not prevent the bone from remodeling in response to the thin buccal plate (3). The resulting functional and esthetic defects are insidious. There may not be any clinical or radiographic findings until after the final restoration is in place. Therefore, it is imperative that before placing implants, the surgeon verifies a minimum of 2 mm of bone facial to the implant. This may be difficult to assess without flapping the surgical site. Subsequently, there is greater predictability in augmenting the bone before or at time of implant placement than years after restoration.

Treatment

Goals of therapy were to re-establish a buccal alveolar plate of adequate thickness and generate keratinized gingiva adjacent to the left central implant. Since there were no significant probing depths adjacent to the implants, there was no bacterial contamination of the implant surfaces. It was therefore reasoned that if the connective tissue adherent to the exposed implant surfaces was removed and the area treated with a guided bone regeneration procedure, the buccal alveolar plate could be regenerated.

The final restorations were removed and replaced with acrylic provisionals which were also screw retained. Surgical therapy was done under local anesthesia. The flap design included a buccal intrasulcular incision from the distal line angle of tooth no. 7 to the interproximal space between teeth 11 and 12. Within the large interproximal space was a good band of keratinized gingiva allowing for a vertical incision towards the bicuspid, then angling to the mesial, as the incision was extended apically. This provided for a tension-free mesial lateral sliding flap at closure. Exposure of the defect revealed large buccal fenestrations over both implants (Fig. 5). There was a bridge of bone of 2–3 mm, superior to the fenestrations on the buccal aspects of both implants. Buccal to the left central, the alveolus was less than 1 mm thick, and on the right central it was 2–3 mm thick. It is suspected that this was why the tissue receded facial to the left central and not facial to the right central. The bone and implant surfaces were débrided of any soft tissue. The defect was grafted with mineralized freeze-dried bone 0.25–1.0 mm cancellous allograft (Puros; Zimmer Warsaw, IN, USA) (Fig. 6). The graft was covered with an absorbable collagen membrane (Resolut LT; W.L. Gore & Associates, Flagstaff, AZ, USA) which was stabilized with six titanium bone tacks (Ace Surgical; Ace Surgical Supply Co, Brackton, MA, USA) (Fig. 7). The flap was advanced coronally and mesially, then closed with ten 5.0 Novafil sutures (Covidien, Mansfield, MA, USA) (Fig. 8). Sutures were removed at 2 weeks.

Six months after the grafting procedure, the area was exposed as part of a connective tissue grafting procedure (Fig. 9). A frenectomy was performed along with the placement of a connective tissue graft from the palate to enhance the soft tissue between the central incisor implants. The flap was sutured with seven 5.0 plain gut sutures. A 2-year postgrafting photograph was taken to show the stability of the repair (Fig. 10).

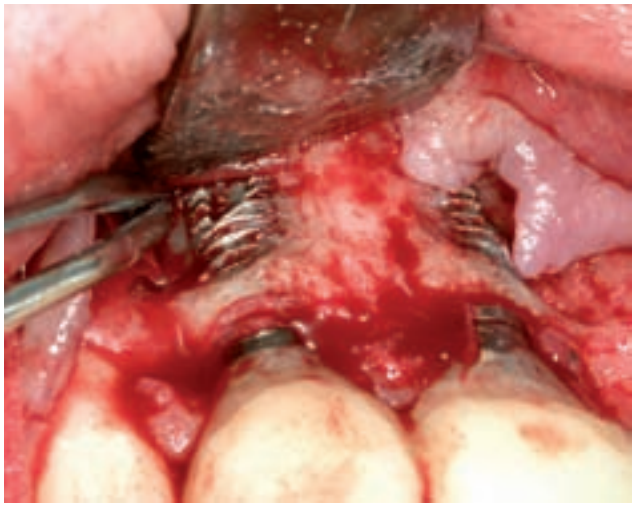


Fig. 5 Open flap view of defects. The crestal bridge of bone was much thicker on the right central incisor implant.

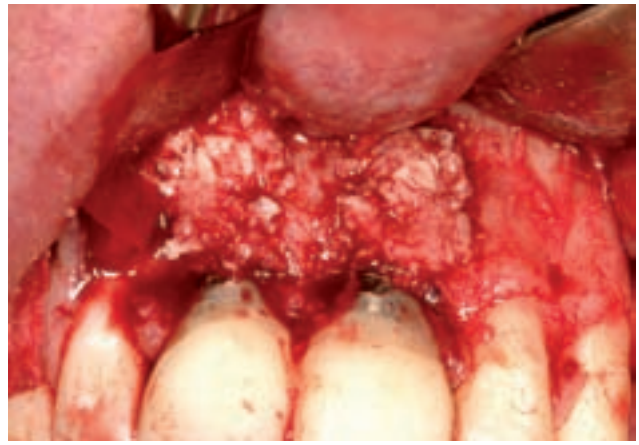


Fig. 6 Mineralized bone allograft in place.

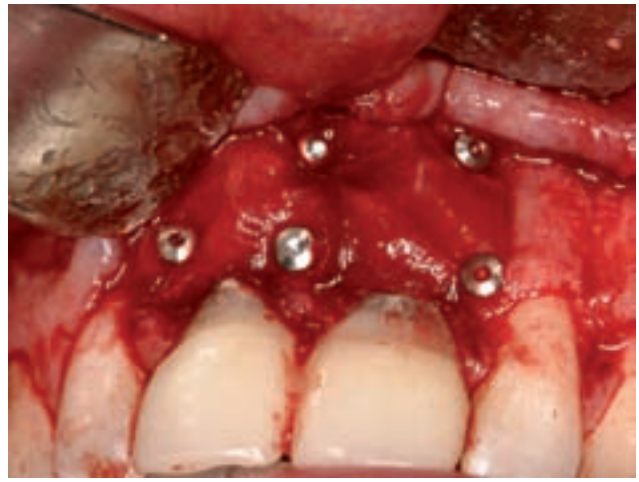


Fig. 7 Stabilized collagen membrane over the allograft.

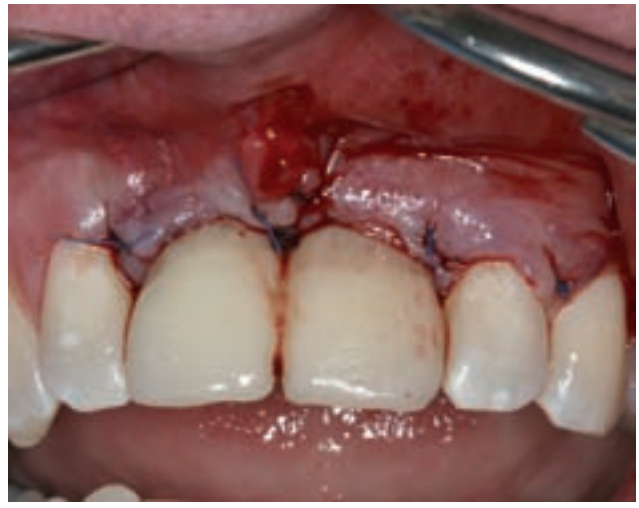


Fig. 8 Flap advancement and closure.

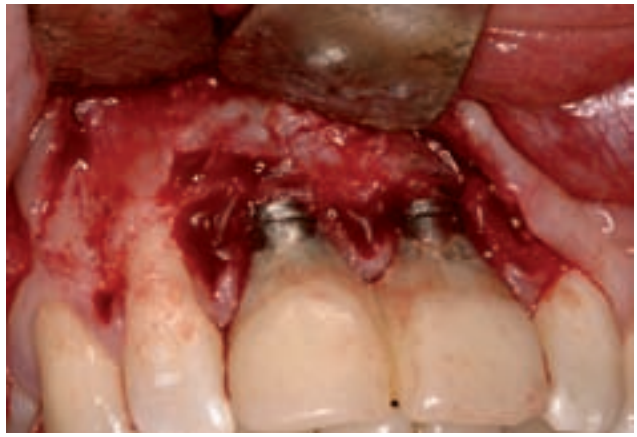


Fig. 9 Flap reflection 6 months after initial grafting to repair soft-tissue contours with a connective-tissue graft.

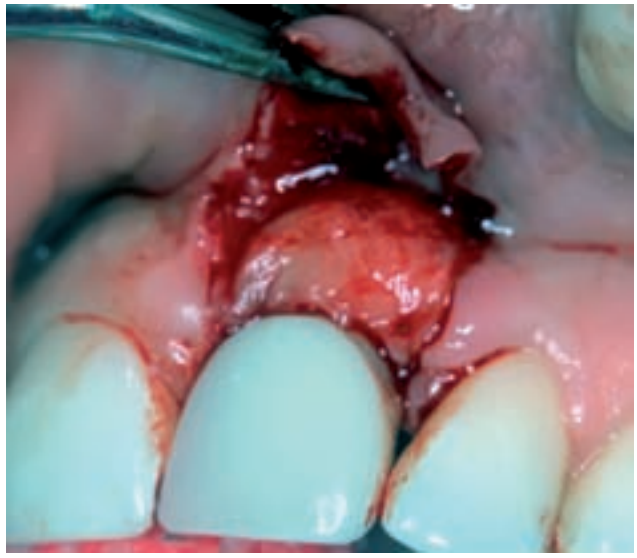


Fig. 10 Final healing 2 years postgrafting indicating stability of soft-tissue levels.

References

1. Spray JR, Black CG, Morris HF, Ochi S. The influence of bone thickness on facial marginal bone responses: stage 1 placement through stage 2 uncovering. *Ann Periodontol* 2000; **5**: 119–28.
2. Grunder U, Gracis S, Capelli M. Influence of the 3-D bone-to-implant relationship on esthetics. *Int J Periodontics Restorative Dent* 2005; **25**: 113–19.
3. Araujo MG, Wennstrom JL, Lindhe J. Modeling of the buccal and lingual bone walls of fresh extraction sites after implants installation. *Clin Oral Implants Res* 2006; **17**: 606–14.

Case 3: Repair of failed esthetic implant case

Bobby Butler DDS

The patient presented with two one-piece solid implants that were placed in the maxillary lateral incisor sites (Fig. 1a). The previous clinician had made three attempts to perform connective tissue grafts (CTGs) to augment the deficient facial and papillary areas without success. At this point in her treatment the patient was referred to my periodontal office. The solid one-piece abutments were showing and significant scar tissue was present (Fig. 1b). Several treatment options were considered in consultation with the patient, prosthodontist, and periodontist. The esthetic goal was to coronally position the gingival levels on both implant sites and restore the papilla form on the adjacent teeth. One complicating factor was the one-piece implant design, which does not allow for submerging the implants. With standard implant systems the abutment can be removed and a CTG can predictably be performed. Another issue was the close proximity of the implants to the adjacent teeth. Removing the implants with a trephine would have possibly damaged one or both of the adjacent teeth. The canines were already restored and it was decided to carry out cantilever fixed bridges after augmenting the pontic sites.

Etiology

The etiology of the complication seen in this case has been discussed in Chapter 11. In brief, the implant was placed in a site with deficient hard and soft tissue. Moreover, the emergence angle of the implant placement was too far buccally. In addition, there was no

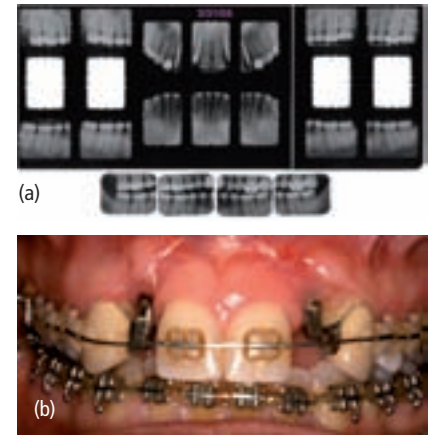


Fig. 1 (a) Pretreatment radiographs. Solid one-piece implants seen in sites 7 and 10. (b) Large soft-tissue deficiencies noted on both implant sites. Missing papillae are noted mesial to both canines. The rough Ti-unite surface is exposed on no. 7.

keratinized tissue on the buccal aspect of the one-piece implant. The soft-tissue deficiencies were complicated and had probably been worsened by the three previous attempts to augment the tissue.

Prevention

Proper implant three-dimensional positioning in a site with sufficient bone is necessary for a successful esthetic result. If the crestal bone on the teeth adjacent to the implant is deficient interproximally, the papillae will be deficient. Orthodontic extrusion of the adjacent teeth can move the interproximal bone coronally. Buccal soft-tissue deficiencies in keratinized tissue should be treated with CTGs before implant placement. Use of one-piece implants in the esthetic zone is very technique sensitive and does not allow angulated abutment placement or submerged correction.

Treatment

Surgery 1

Palatal pedicle connective tissue grafts were completed on both sites (1–6). The abutments were cut off with a high-speed handpiece slightly above the osseous crest. Full-thickness palatal flaps were elevated from the second molars to the central incisors. A split-thickness subepithelial pedicle was dissected and then rotated over the now submerged implants (Fig. 2a). (The pedicle was inserted under the facial flap and the flap closed with 6.0 Vicryl sutures.) The facial flaps were predominantly full-thickness flaps with apical split-thickness periosteal releasing incisions. The right facial flap had a vertical release distal–facial to no. 6 and sulcular incision extending to no. 8. The left facial flap was similar except that a second vertical incision was completed obliquely over no. 9 to avoid lifting the papilla (Ethicon PC-3 needle, 6.0 Vicryl). The tails of the grafts were extended over the facial ridge and tucked under the facial flaps. The flaps were closed with a small portion of the graft exposed (Fig. 2b). Vertical incisions were closed with 7.0 Vicryl sutures on the distofacial, mesiofacial, and distofacial, respectively, of teeth numbers 6, 10, and 11 with 7.0 Vicryl sutures (Fig. 2c).

At the 3-week follow-up, healing was progressing well (Fig. 2d). Excellent gain was seen in the facial and papillary gingival volume. The implants with the resected abutments remained submerged.

Surgery 2

A second graft was performed on both sides with tunnel procedures aimed at further increasing gingival volume (7, 8). Vestibular incisions were made and the subepithelial CTGs were inserted (Fig. 3a). The CTGs were positioned and immobilized with horizontal mattress sutures through the undermined facial gingiva. The vestibular incisions were closed with interrupted 7.0 Vicryl sutures. The palatal donor site for the pouch CTGs is shown in Fig. 3(b). Significant improvements were made on the left side, but not on the right side. The papilla on the distal of the right central incisor was still deficient.

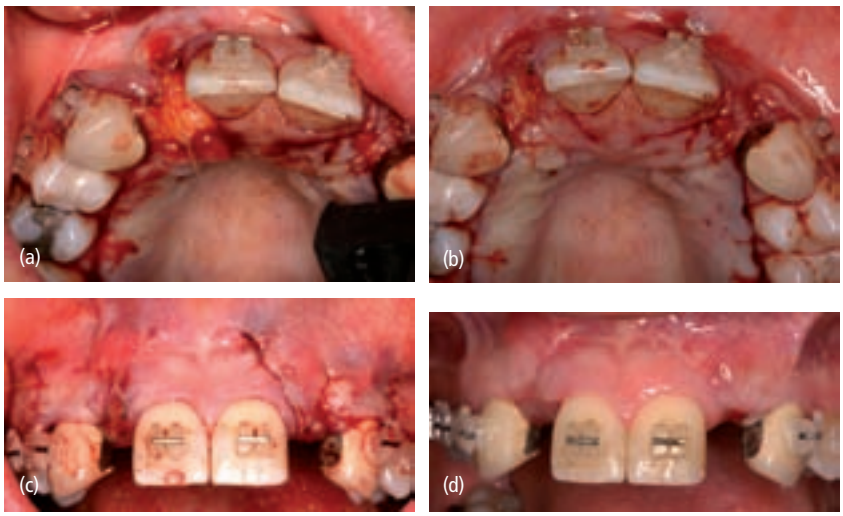


Fig. 2 (a) Palatal pedicle connective tissue grafts were used to cover the implants. The image shows the right side sutured. The left facial flap is being advanced over the pedicle connective tissue graft. (b) The pedicle donor sites were closed with primary closure. The recipient sites had 3–4 mm of the pedicle grafts exposed. (c) The gain in horizontal and vertical soft-tissue volume is seen immediately after the first surgery. (d) The implants have been submerged. The papillary and facial gingival levels have increased significantly after the first surgery.

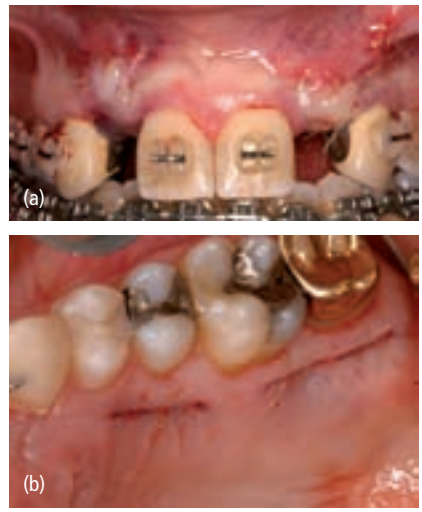


Fig. 3 (a) The pouch–tunnel incisions are closed with 7.0 Vicryl sutures. The goal was to increase the horizontal and vertical gingival volume in the pontic sites. (b) Closure of the single incision donor sites.

Surgery 3

A third CTG was completed on the right side. The graft at this point was the sixth CTG the patient received over a 2-year period. This area, especially on the distal of the right central incisor, was worse than it was after the first surgery (Fig. 4). This last graft was also a palatal pedicle CTG wrapped over the pontic site toward the distal of no. 9 to augment the papilla (Fig. 5a). A facial view shows the CTG wrapping over the distal surface of the central incisor (Fig. 5b). The final restoration included the two-unit fixed restorations with the lateral incisor pontics cantilevered off the canine teeth. Use of the ovate pontics allowed better control over the height of the papilla between the natural teeth and the edentulous lateral incisor areas.

The overall results were excellent on the left side and improved but not ideal on the right side. The repeated surgical events may have compromised the vascular supply and limited the results. Four months of healing time between grafts was allowed. There was dense connective tissue scarring which limited the vascular supply and potential for soft-tissue grafting. Overall, the patient was very pleased with the outcome in spite of her high lip line and the shorter papilla on the distal of no. 8 (Fig. 6).

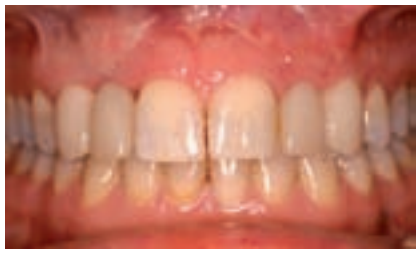


Fig. 4 Following the second connective tissue graft the papilla height has been decreased on the distal of the right central incisor.

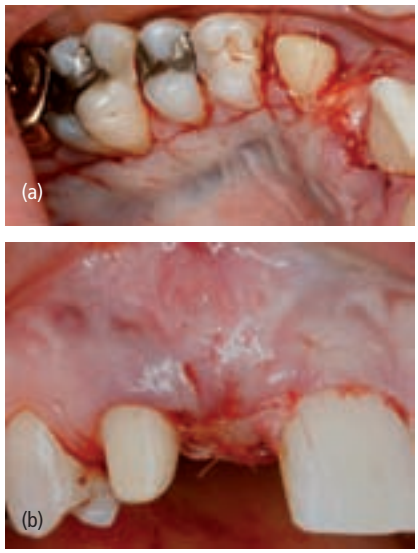


Fig. 5 (a) Palatal closure of the second palatal pedicle connective tissue graft. (b) The graft is seen on the distal of no. 8 and extends under the flap.

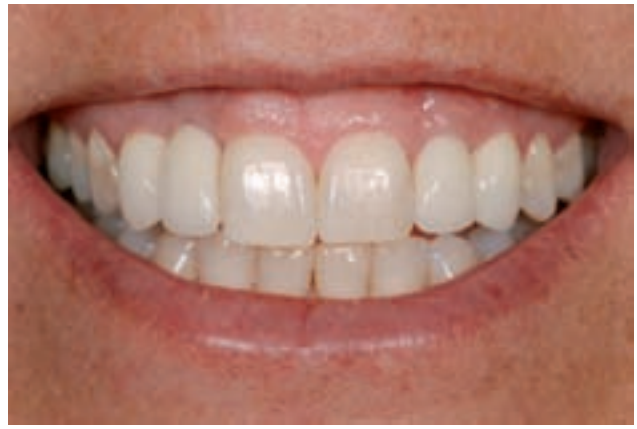


Fig. 6 Final restorations after bleaching the natural dentition and the cantilever fixed partial dentures. The gingival volume and levels are ideal on the left side but still deficient on the right side. (Restorative treatment by Gregg Kinzer DDS, MSD, Seattle, WA.)

References

Palatal pedicle connective tissue grafts

1. Wang PD, Pitman DP, Jans HH. Ridge augmentation using a subepithelial connective tissue pedicle graft. *Pract Periodontics Aesthet Dent* 1993; **5**: 47–51.
2. Nemcovsky CE, Artzi Z. Split palatal flap. I. A surgical approach for primary soft tissue healing in ridge augmentation procedures: technique and clinical results. *Int J Periodontics Restorative Dent* 1999; **19**: 175–81.
3. Nemcovsky CE, Artzi Z, Moses O. Rotated split palatal flap for soft tissue primary coverage over extraction sites with immediate implant placement. Description of the surgical procedure and clinical results. *J Periodontol* 1999; **70**: 926–34.
4. Nemcovsky CE, Artzi Z. Split palatal flap. II. A surgical approach for maxillary implant uncovering in cases with reduced keratinized tissue: technique and clinical results. *Int J Periodontics Restorative Dent* 1999; **19**: 387–93.
5. Khoury F, Happe A. The palatal sub-epithelial connective tissue flap method for soft tissue management to cover maxillary defects: a clinical report. *Int J Oral Maxillofac Implants* 2000; **15**: 415–18.
6. Mathews DP. The pediculated connective tissue graft: a technique for improving unaesthetic implant restorations. *Pract Proced Aesthet Dent* 2002; **14**: 719–24.

Tunnel–pouch connective tissue grafts

7. Allen AL. Use of the supraperiosteal envelope in soft tissue grafting for root coverage, part II: clinical results. *Int J Periodontics Restorative Dent* 1994; **14**: 302–15.
8. Blanes RJ, Allen EP. The bilateral pedicle flap-tunnel technique: a new approach to cover connective tissue grafts. *Int J Periodontics Restorative Dent* 1999; **19**: 471–9.

Case 4: Treatment of an osseous defect associated with an immediately placed implant

Donald S. Clem DDS, FACD

Since the publication of Lazzarra's case report on the placement of a dental implant at the time of extraction, the term "immediate implant placement" has continued to evolve and techniques have been developed (1, 2). While the placement of an implant immediately after tooth extraction has been shown to result in similar outcomes to those placed in healed sites (3), it is not without risks. There is a lack of long-term controlled data regarding hard- and soft-tissue complications and poor esthetic outcomes (4, 5). In 2008, den Hartog *et al.* published a meta-analysis of immediate, early and conventional implant placement in the esthetic zone. While overall survival rate was high (93.0–97.1%) after 1 year, parameters such as esthetic outcomes, soft-tissue levels, health, and patient satisfaction were not well defined (6). The question whether immediate and early-staged implant therapies would result in better treatment outcomes remained inconclusive.

The following case report will demonstrate factors in treatment planning, procedures, and patient response that will discuss complications and treatment solutions made during therapy.

The patient, a 45-year-old woman, presented in no apparent distress. Her medical history was non-contributory. Her dental history, however, revealed blunt trauma received over 10 years previously to the anterior maxilla. No history of fracture or endodontic treatment was given. Her chief complaint was that her "tooth had yellowed" and she sought dental treatment for esthetic improvement. Upon clinical examination, it was determined that the maxillary right central incisor was non-vital and exhibited radiographic signs of external root resorption (Figs 1, 2). It was decided to replace the tooth with a dental implant and since the patient wanted to expedite treatment as much as possible an immediate implant placement was planned at the time of extraction.

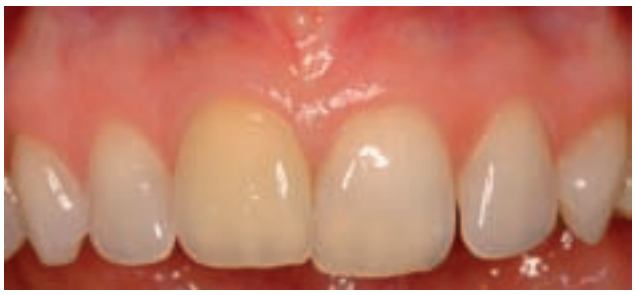


Fig. 1 Clinical appearance of the hopeless maxillary right central incisor tooth 8.

Consideration 1: Are the risks of a difficult extraction a relative contraindication to immediate placement in the esthetic zone?

Following removal of the tooth, a large facial defect was noted at the time of implant placement (Brånemark 3.75 × 15 Ti-unite implant; Nobel Biocare, Yorba Linda, CA, USA), which was partially contained along the facial surface of the implant. The defect was primarily a hard-tissue defect. However, if hard tissue demonstrates incomplete regeneration, a secondary soft-tissue defect often results, as was seen in this case. Figure 3(a) shows the clinical and Fig. 3(b) the radiographic aspects of the implants and defect.

Etiology

If external root resorption is present, routine extraction of the affected teeth can be difficult when preservation of the socket housing is the goal. In this case, a significant portion of the facial wall of bone was ankylosed to the buccal aspect of the root of the tooth and could not be preserved.

Prevention

Prevention of a bony defect caused by the above-mentioned factors in this case could not be avoided.

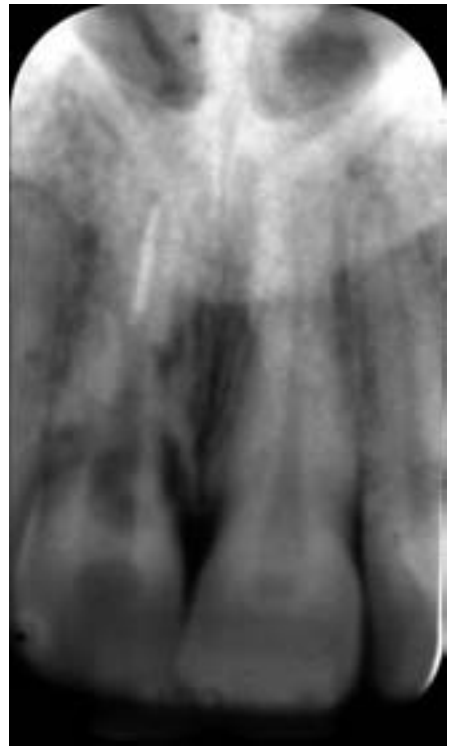
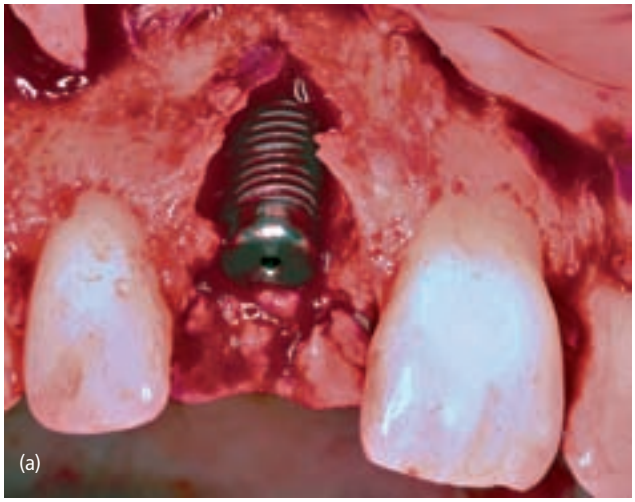


Fig. 2 Radiographic appearance of tooth 8 suggestive of root resorption.



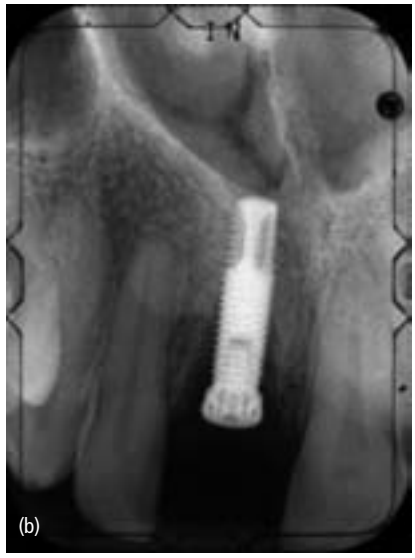


Fig. 3 (a) Implant placement immediately at the time of extraction of tooth 8. (b) Radiographic appearance of implant at the time of placement.

However, the goal of complete bone regeneration before placing a dental implant in compromised cases, such as this, should be considered. A two-stage implant placement protocol should have been employed, first focussing on regeneration of facial bone, and later a second surgery performed with the implant placement.

Treatment

The defect was grafted with demineralized freeze-dried bone allograft (DFDBA) (LifeNet Health, Virginia Beach, VA, USA) and an absorbable membrane (OraPharma, Warminster, PA, USA). A removable partial was used for temporization. Sixteen weeks after implantation, however, the soft-tissue contours continued to retract with loss of interdental papillae (Fig. 4).

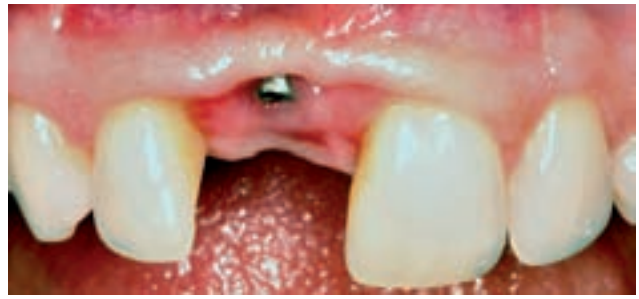


Fig. 4 Loss of tissue and papilla 6 weeks after initial implant placement.

Consideration 2: What was the cause of the soft-tissue loss and how can contour and volume be improved before final restoration?

To achieve adequate soft-tissue volume and contours, underlying bone volume must be sufficient to support the soft tissue desired. It was decided that additional bone and soft tissue would be necessary to support the esthetic demands of the final restoration. From a functional standpoint the implant appeared to be well integrated clinically and radiographically. Upon full-thickness flap reflection, much of the facial defect was restored with the initial graft at the time of implant placement. It was noted, however, that the bone regeneration was incomplete on the facial surface which, therefore, did not support the facial soft tissue. Moreover, interdental contours were compromised (Fig. 5). From a clinical standpoint, implants with partial dehiscence/fenestration defects can survive functional loading well (6). Esthetically, however, cases of incomplete bone formation can contribute to a compromised result, as demonstrated here. The treatment required that bone be augmented to support the necessary soft-tissue volume required for a more esthetic result.

DFDBA has been extensively used with success to regenerate bone in both periodontal and implant site applications (7). DFDBA has a faster turnover rate than mineralized bone substitutes and typically yields new

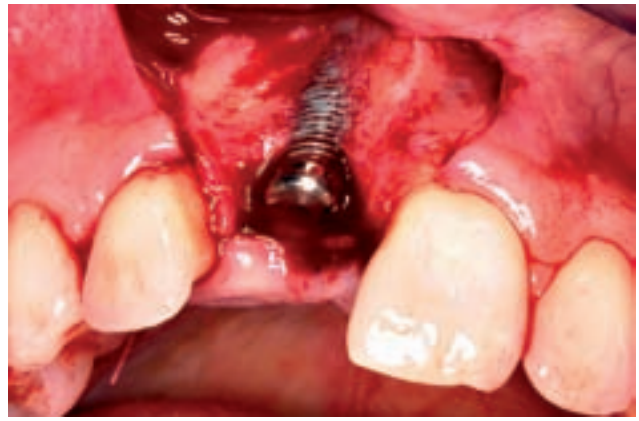


Fig. 5 Incomplete facial bone regeneration.

bone formation in the 40% range when used in combination with resorbable members for implant site development (8). The question of whether or not this new bone actually integrates with the implant surface, however, is controversial. Most of the published data have focussed on attempts to establish "reintegration" of implant threads as a treatment for peri-implantitis. Histologic studies have included surfaces not previously exposed to the oral environment with exposed threads. In the former cases, data indicate that reintegration may not be possible. However, there is a paucity of studies on this topic (9–12). Clearly, unsupported soft tissue will either not be stable or result in excess probing depth which may lead to long-term maintenance problems. The goal of the corrective procedure in this case was to support soft tissue and not necessarily to gain additional integration. DFDBA was therefore used to build facial contour and a long-term absorbable membrane was placed for wound stabilization (Figs 6, 7). In addition, an autogenous connective tissue graft with coronally advanced flaps was used to improve facial and interproximal soft-tissue contours (Fig. 8). Sixteen weeks postoperatively, a "punch" uncovering was done to gain access to the implant head. The improved quantity and quality of soft tissue and facial contour as a result of this corrective grafting can be seen in the clinical and radiographic photographs (Fig. 9). A provisional fixed restoration was then placed to aid in the contouring of the soft tissue and was kept in place for an additional 3 months. Gingivoplasty was then performed to mimic the contours of the adjacent central incisor (Figs 10, 11). Approximately 3 months later the final restoration was placed and the 2.5-year postloading result is shown clinically and radiographically (Figs 12–14).

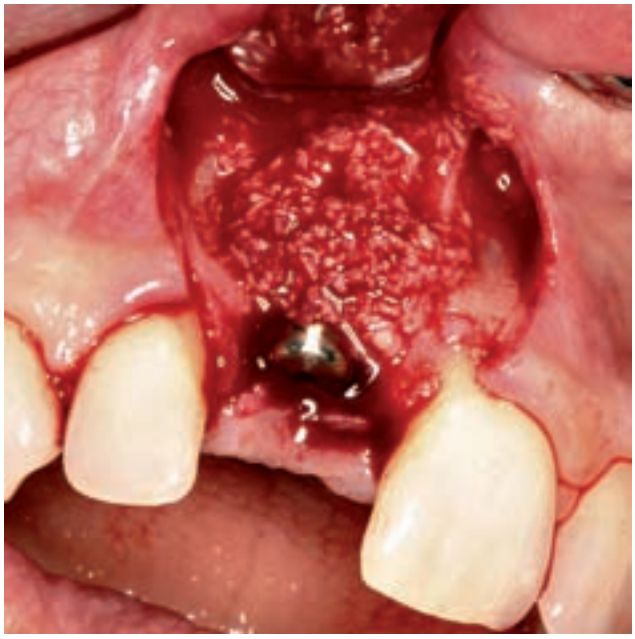


Fig. 6 Decalcified freeze dried bone allograft (DFDBA) facial graft in place.

Summary

- Difficult extractions, particularly in cases of root resorption/ankylosis may carry an increased risk for incomplete bone regeneration.

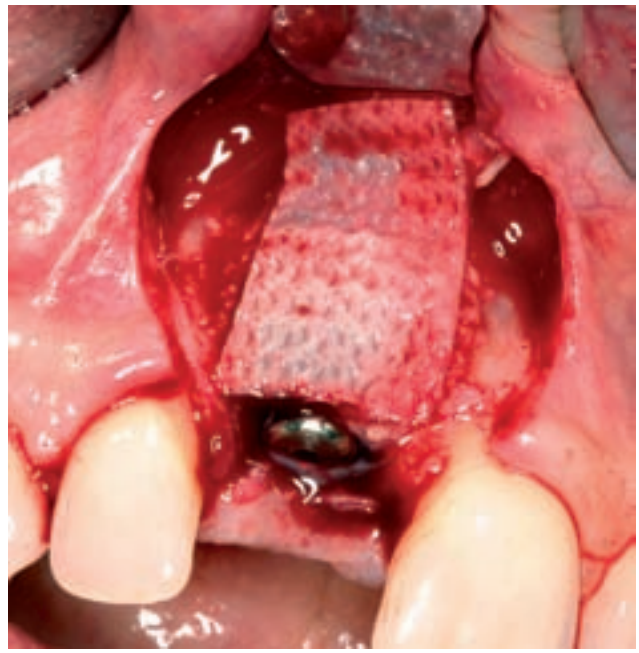


Fig. 7 An absorbable membrane over the graft.

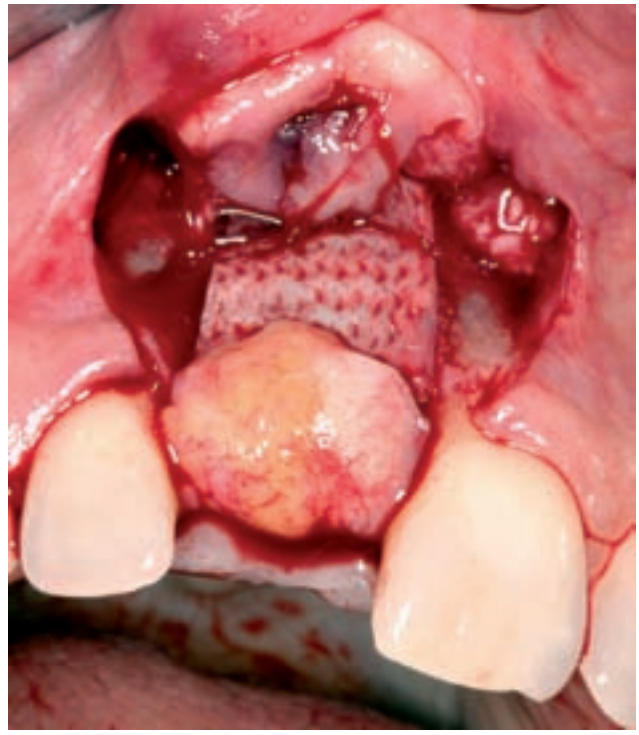
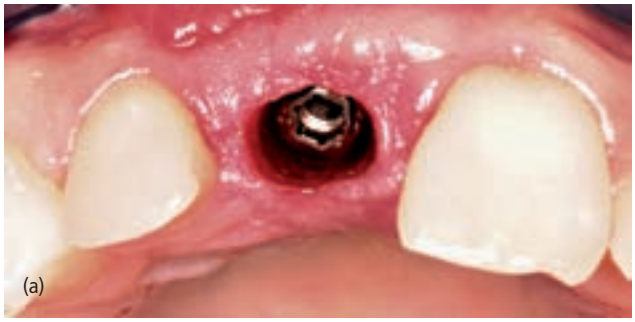


Fig. 8 Subepithelial connective tissue graft in place.



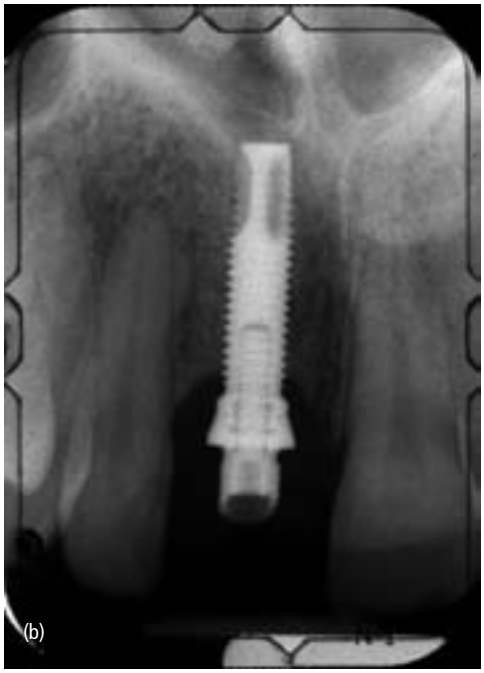


Fig. 9 Improved soft-tissue contour.

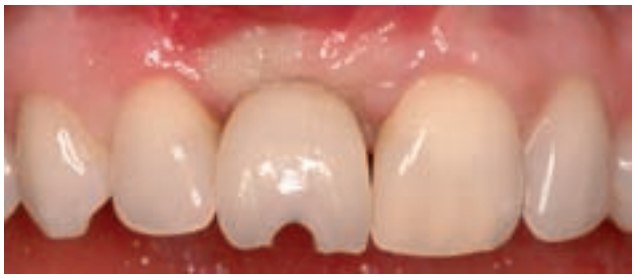


Fig. 10 Provisional in place.

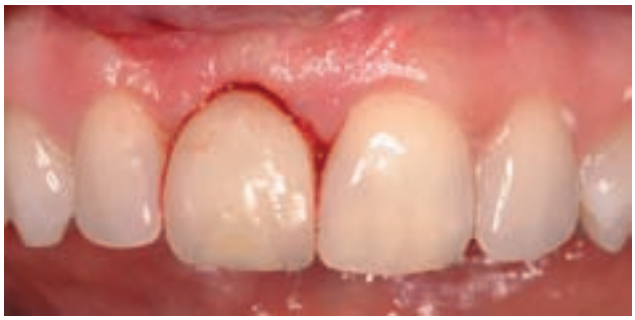


Fig. 11 Gingivoplasty 3 months after provisional restoration.

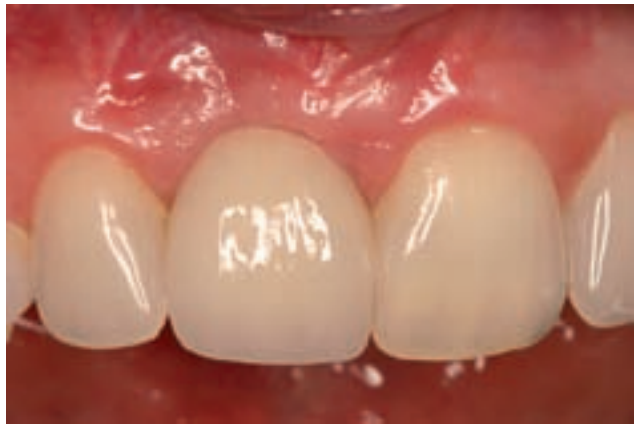


Fig. 12 Final restoration 2.5 years postsurgery. (Final restoration by Thomas Thompson DDS.)

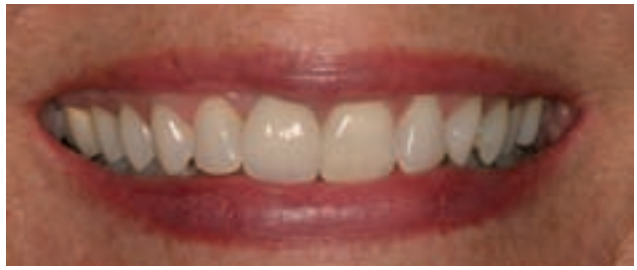


Fig. 13 The 2.5-year postoperative appearance of papilla maintenance.

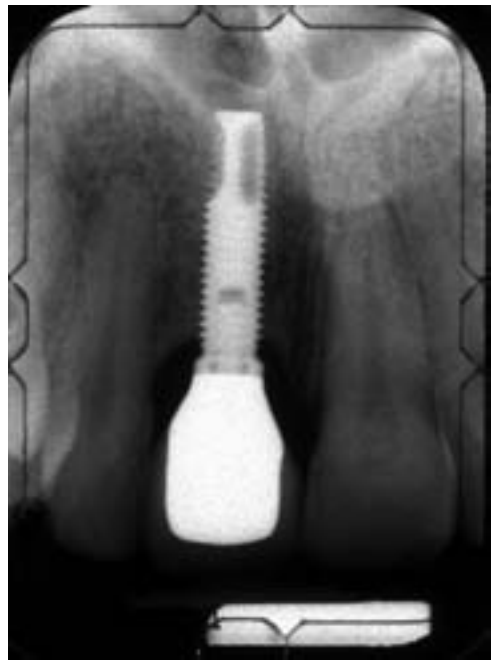


Fig. 14 The 2.5-year postoperative radiographic appearance.

- Adequate soft tissue is necessary for esthetic outcomes and requires sufficient volume of bone for long-term support.
- Fixed provisional restorations following extensive grafting procedures help the surgeon in evaluating and developing the final soft-tissue contours before final restoration.
- Guided bone regeneration with DFDBA in combination with a barrier membrane and an autogenous connective tissue graft can be an effective method of defect correction.

References

1. Lazzarra RJ. Immediate placement of implants into extraction sites: surgical and restorative advantages. *Int J Periodontics Restorative Dent* 1989; **9**: 332–43.
2. Schwartz-Arad D, Chaushau G. The ways and wherefores of immediate placement of implants into final extraction sites: a literature review. *J Periodontol* 1987; **68**: 915–23.
3. Schropp L, Isidor F, Kostopoulos L, Wenzel A. Interproximal papilla levels following early versus delayed placement of single-tooth implants. *Int J Oral Maxillofac Implants* 2005; **20**: 753–61.
4. Chen ST, Wilson TG, Hammerle CH. Immediate or early placement of implants following tooth extraction: review of biologic basis, clinical procedures, and outcomes. *Int J Oral Maxillofac Implants* 2004; **19** (Suppl): 12–15.
5. Esposito MA, Koukoulopoulou A, Coulthard P, Worthington HV. Interventions for replacing missing teeth: dental implants in fresh extraction sockets (immediate, immediate–delayed and delayed implants). *Cochrane Database Syst Rev* 2006; (4): CD005968.
6. den Hartog L, Slater JJ, Vissink A, Meijer HJA, Raghoebar GM. Treatment outcomes of immediate, early and conventional single-tooth implants in the esthetic zone: a systematic review to survival, bone level, soft-tissue, aesthetics and patient satisfaction. *J Clin Periodontol* 2008; **35**: 1073–86.
7. Nevins M, Mellonig JT, Clem DS, Reise GM, Buser D. Implants in regenerated bone: long term survival. *Int J Periodontics Restorative Dent* 1998; **18**: 534–9.
8. Clem DS. Implant site development using guided bone regeneration techniques. *Compend Contin Educ Dent* 2000; **21**: 424–30.
9. Cammack GV, Nevins M, Clem DS, Hatch J, Mellonig J. Histologic evaluation of mineralized and demineralized freeze-dried bone allograft for ridge and sinus augmentations. *Int J Periodontics Restorative Dent* 2005; **25**: 345–62.
10. Machado MA, Stefani CM, Treatment of ligature induced peri-implantitis by regenerative procedures. Part II. A histologic study in dogs. *J Oral Sci* 2000; **42**: 163–8.
11. Nociti FH, Caffesse RG. Evaluation of guided bone regeneration and/or bone grafts in the treatment of ligature induced perio-implantitis defects: a morphometric study in dogs. *J Oral Implantol* 2000; **26**: 244–9.
12. Hammerle CH, Jung RE, Feloutzis A. Systematic review of the survival of implants in bone sites augmented with barrier membranes in partially edentulous patients. *J Clin Periodontol* 2002; **29** (Suppl 3): 226–31; Discussion 232–3.

Case 5: Treatment of bone loss from an acute abscess around a dental implant

Bradley S. McAllister DDS, PhD

An 82-year-old man with type 2 diabetes (moderate control, recent HbA_{1c} of 7.2%) presented considering dental implants to replace two missing posterior teeth in the mandible. After proper consent was obtained, the patient was treated by placing two Brånemark implants (Ti-unite surface) (Nobel Biocare, Yorba Linda, CA, USA) in a single-phase surgery with no bone grafting (Fig. 1a, 1b). Owing to a complete lack of keratinized tissue around the posterior fixture (Fig. 2), a free gingival graft was the treatment planned to follow the 4-month integration healing period. Twelve weeks into the healing a routine evaluation revealed a localized abscess on the posterior implant (Fig. 3).

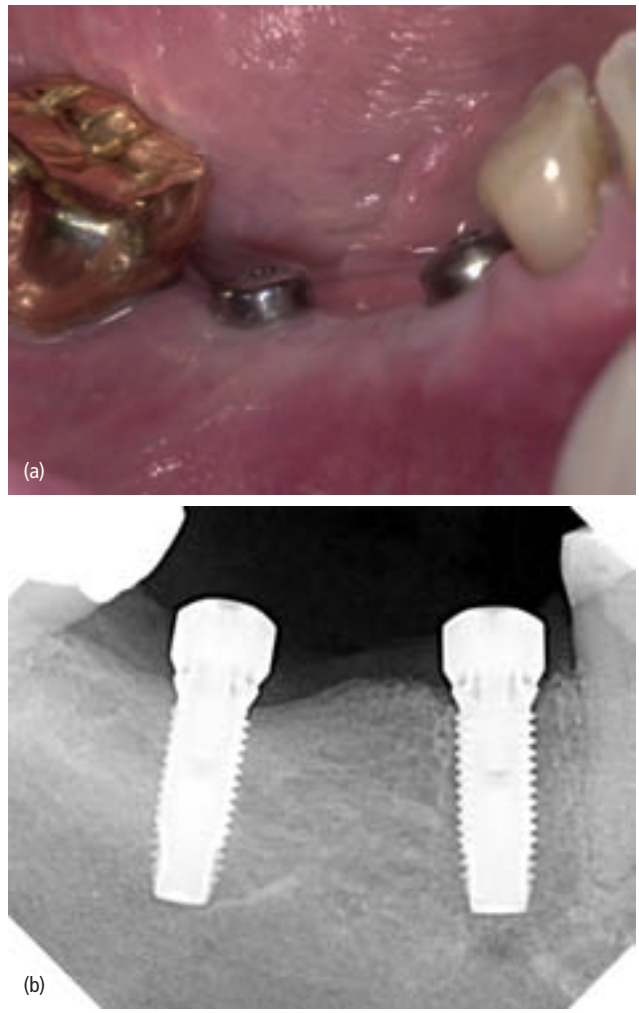


Fig. 1 (a, b) Postoperative clinical picture showing the two implants placed as a single-phase surgery with a radiographic view.

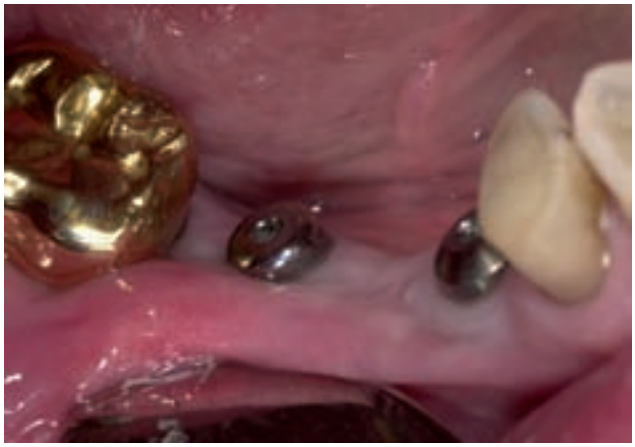


Fig. 2 Postoperative clinical picture showing the complete lack of keratinized tissue on the posterior implant.

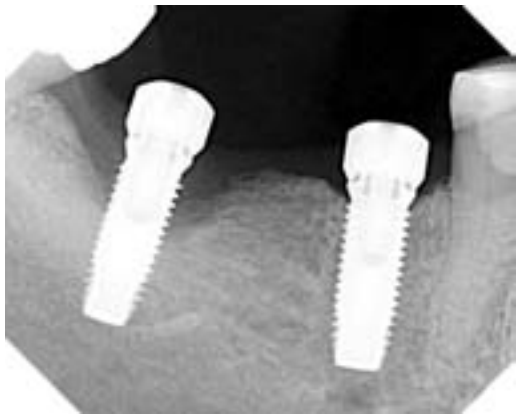


Fig. 3 Digital radiograph showing the bone loss found on the distal implant at the patient's 12-week evaluation.

Etiology and prevention

A retrospective analysis of this case identified multiple risk factors that could have been addressed to reduce the risk of complication. The patient was an elderly man with suboptimal oral hygiene, moderately controlled diabetes, and minimal keratinized tissue. This case could have been treated with a classic two-phase approach. Submerging the implant and performing a free gingival graft at the uncovering surgery would have lowered the risk of complication. In addition, more effort with home-care and blood glucose control could have been initiated before implant placement surgery.

Treatment

The area of bone destruction was surgically treated with systemic amoxicillin (500 mg three times daily for 7 days), full-thickness flap reflection, defect degranulation (Fig. 4), and a 2-minute scrubbing of the implant with multiple cotton pellets saturated with a slurry consisting of one 250 mg capsule of tetracycline in 1 ml of sterile water for detoxification (Fig. 5). To regenerate the lost bone, a graft of cancellous anorganic bovine bone (Bio-Oss; Osteohealth, Shirley, NY, USA) was placed in the defect (Fig. 6) and a collagen membrane (Bio-Gide; Osteohealth) was used for coverage (Fig. 7). The healing abutment was replaced with a cover screw, primary closure was obtained (Fig. 8), and the implant was submerged for 5 months (Fig. 9). Radiographic evaluation during the healing period showed maturation of the

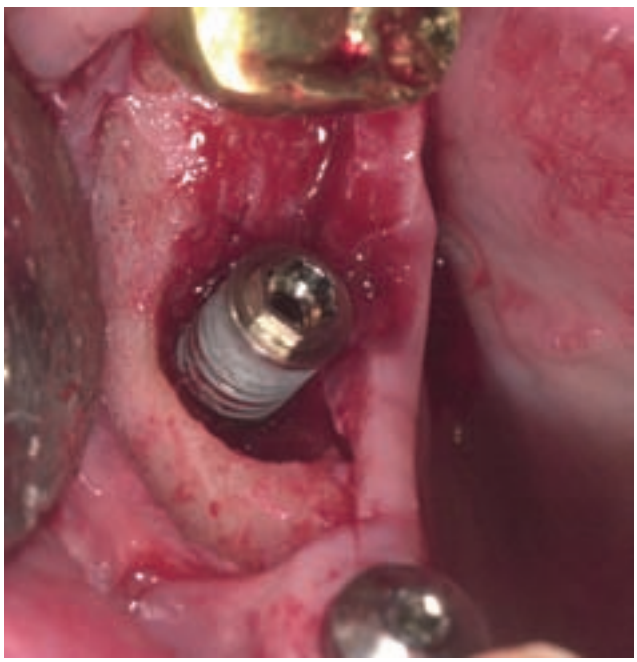


Fig. 4 The bone defect surrounding the posterior implant has been completely degranulated.

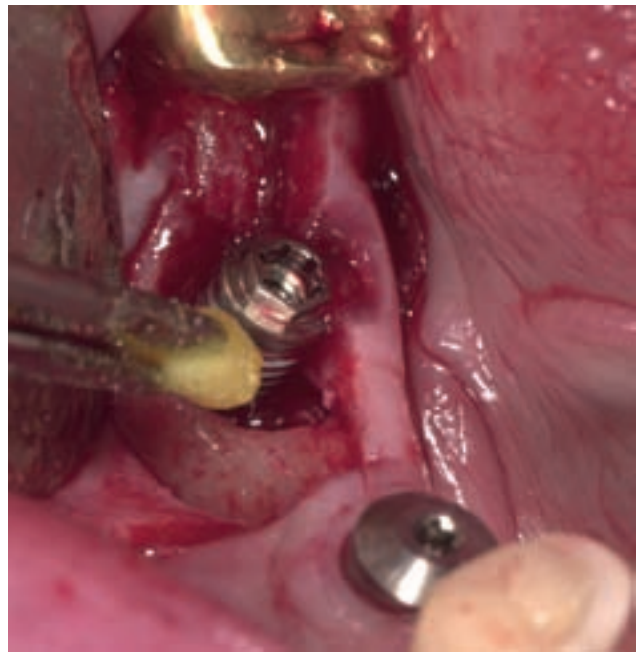


Fig. 5 The implant was scrubbed for 2 minutes with multiple cotton pellets saturated in a tetracycline slurry.

bone graft (Figs 10–12). Uncovering of the fixture and placement of a free gingival graft were performed 5 months postoperatively (Figs 13, 14). The final restoration was then completed by Dr Adam Francois (Sherwood, OR, USA) using a splinted fixed bridge (Fig. 15). His follow-up, for over 5 years, has included 3-month recalls with oral hygiene instruction (OHI) and yearly radiographs (see 5-year follow-up shown in Figs 16 and 17).

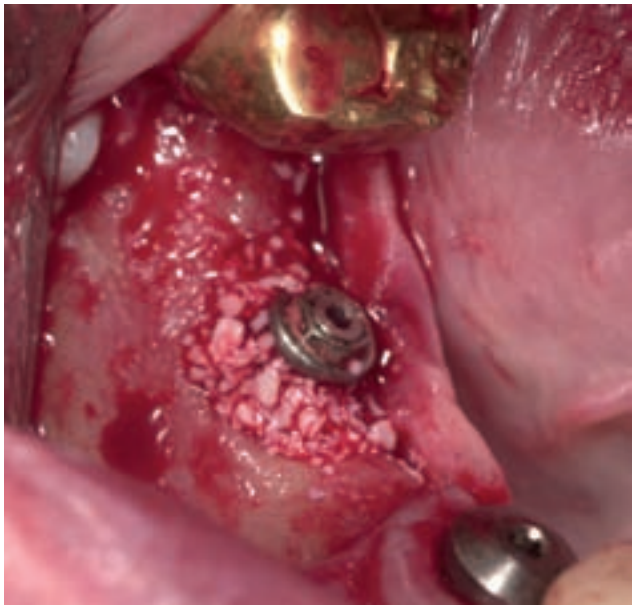


Fig. 6 The bone graft has been placed.

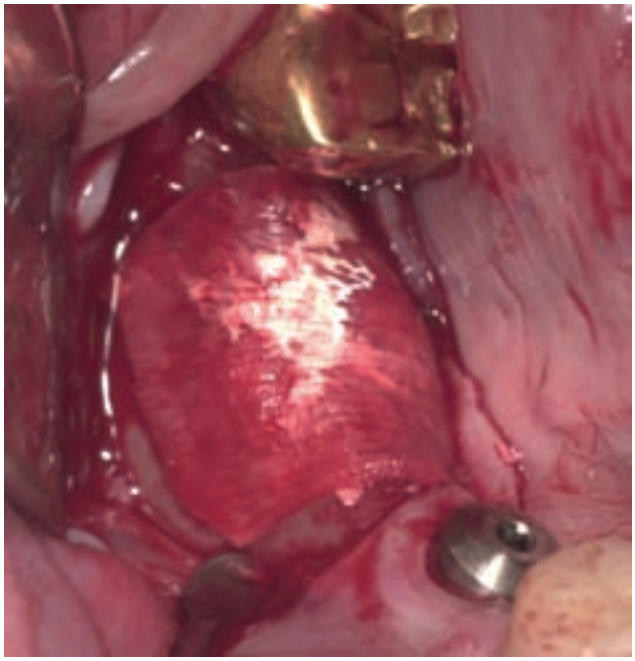


Fig. 7 The collagen membrane has been placed.

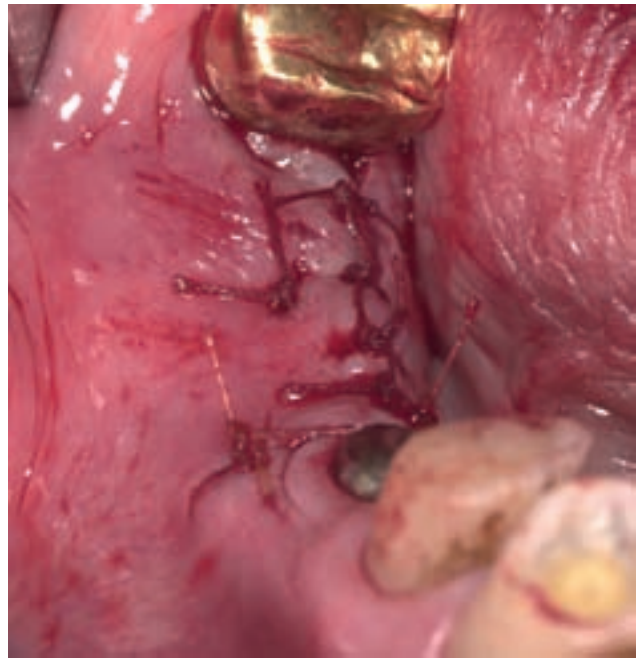


Fig. 8 Primary coverage was obtained with Vicryl suturing over the membrane and bone graft.

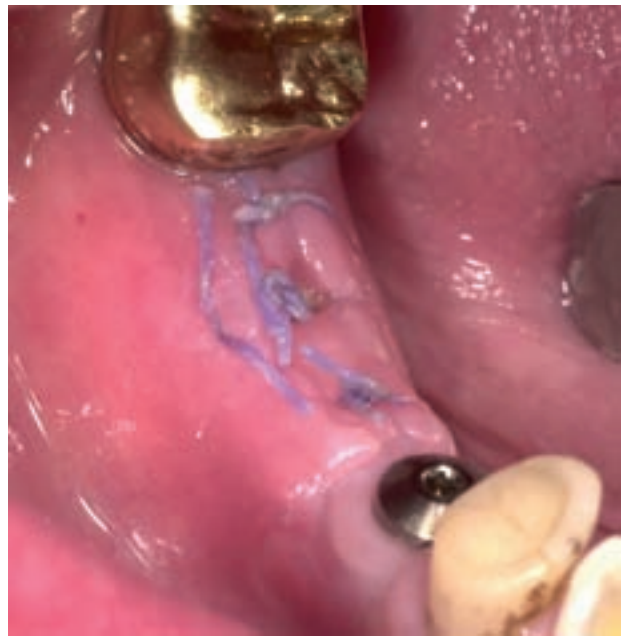


Fig. 9 One-week postoperative view of the repair site.

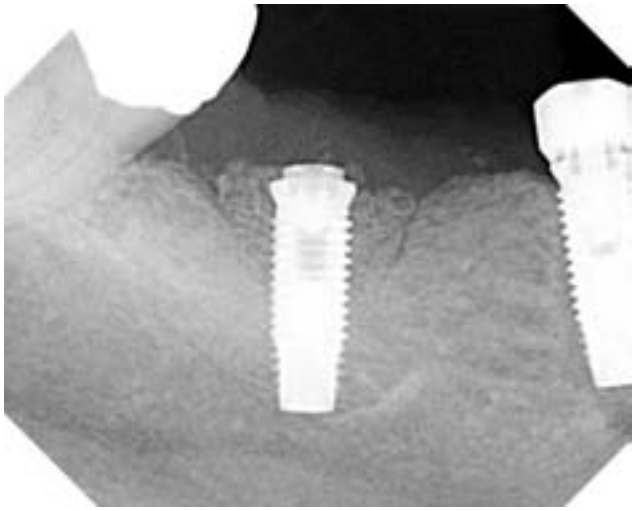


Fig. 10 Radiograph of the bone graft on the day of the repair.

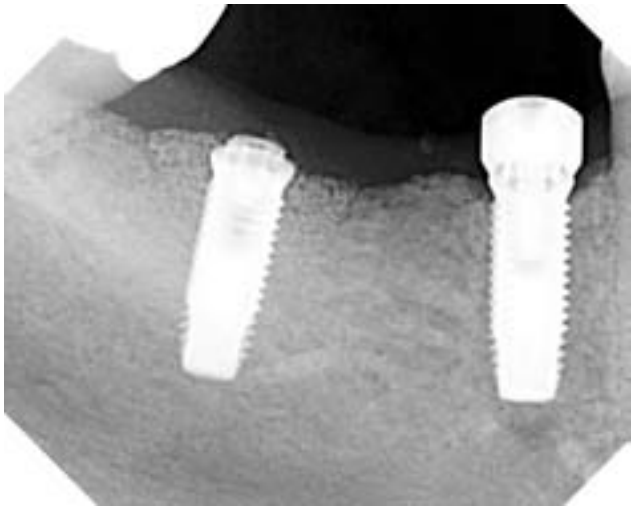


Fig. 11 Radiograph of the bone graft taken 2 months after the repair.

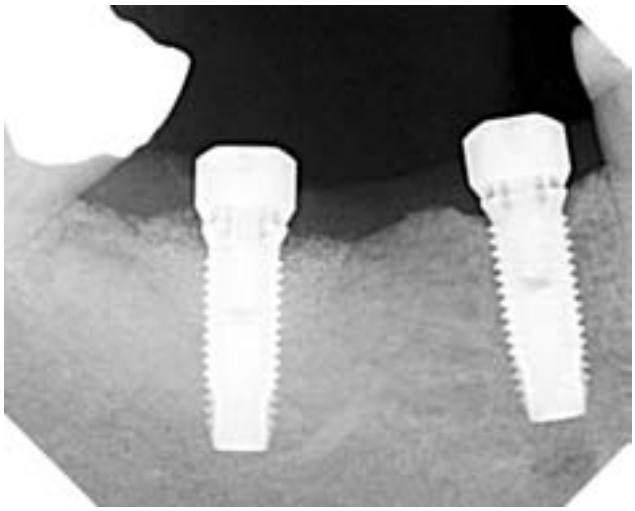


Fig. 12 Radiograph of the bone graft taken 5 months after the repair.

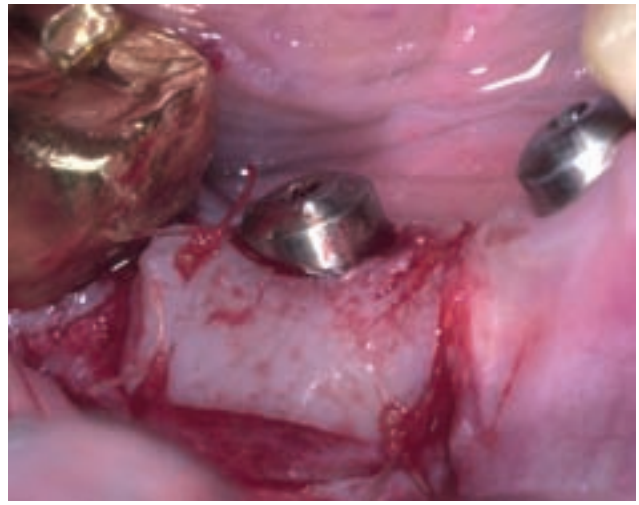


Fig. 13 At the time of placing the healing abutment a free gingival graft was sutured in place using 5-0 chromic gut suture material.

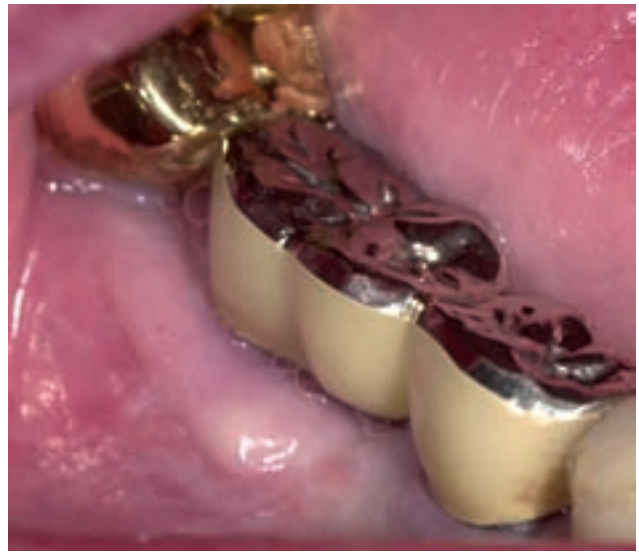


Fig. 14 Six weeks postoperative clinical view of the free gingival graft.

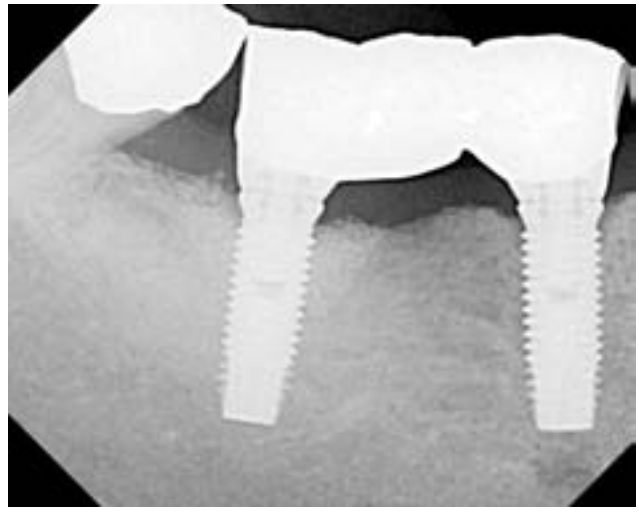


Fig. 15 Radiographic presentation of the final restoration.

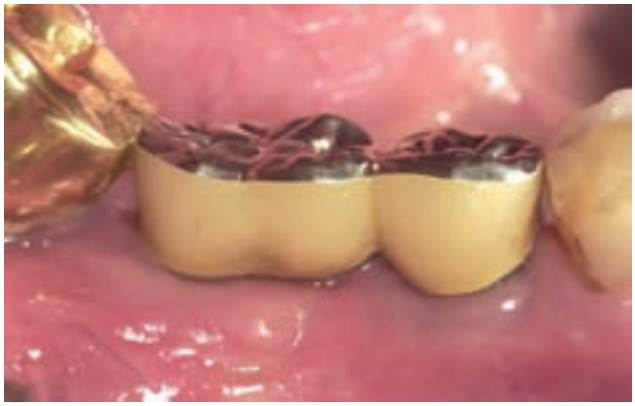


Fig. 16 Five-year postrepair clinical presentation.

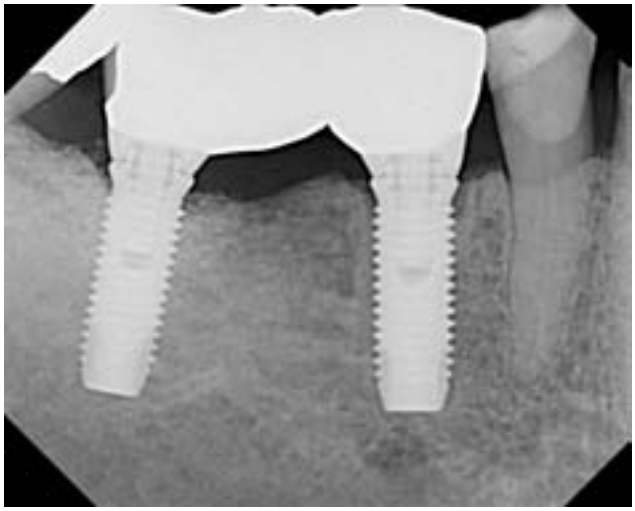


Fig. 17 Five-year postrepair radiographic presentation.

Case 6: Replacement of a failed implant in the esthetic zone

Abd Elsalam Elaskary BDS

The flapless implant placement protocol is increasingly being used because it offers several clinical advantages. However, the technique requires a strict meticulous clinical technique to achieve optimal treatment outcomes (1, 2). There are some factors that are considered detrimental to this treatment modality, including a lack of direct visibility (being a blind technique) and the need to use a computer axial tomographic (CAT) scan either for preoperative examination or for confirmation of optimal implant position. The latter presents an additional cost to the patient. In addition, as with any implant placement procedure; there is a need to achieve primary implant stability. This can be achieved by either exceeding the socket apex by a minimum of 3–4 mm, or engaging the labial and lingual cortical plates of bone in cases where there is insufficient apical bone or where a vital anatomic structure is present (3).

Often complications may include incorrect implant position caused by an imprecise surgical template, the lack of control during the drilling procedure, the presence of unfavorable tissue, and poor presurgical planning caused by a lack of knowledge or experience (4, 5)

A 28-year-old male patient was referred with a chief complaint of looseness of the implant-supported maxillary left central incisor restoration which he reported was placed with flapless surgery (Fig. 1). A clinical and radiographic examination (Fig. 2) revealed a mobile implant with a deficiency of the labial soft-tissue thickness, recession of the soft-tissue margin, and an asymmetric implant-supported restoration. The patient reported that the restoration was completed 4 months before the current visit.

Etiology

The implant was easily removed (Fig. 3). After obtaining a radiographic and clinical history, it was concluded that

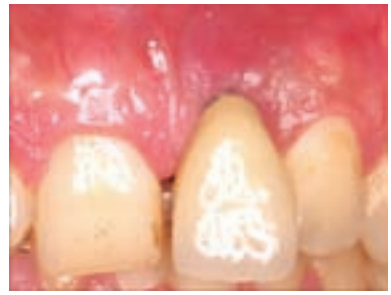


Fig. 1 Failed implant-supported restoration. Note the amount of bone loss with subsequent soft-tissue loss.

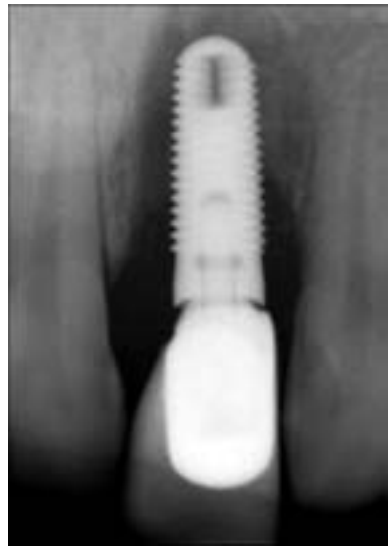


Fig. 2 Radiographic view showing the failed implant, along with the bone loss pattern. Note the short implant length.

Fig. 3 The failed implant and the suprastructure after extraction.

the etiology of this failed implant was related to a deficiency of bone at the surgical site, use of a short implant resulting in poor crown-to-root ratio, a poorly fitting restoration, and occlusal overload of the implant.

Prevention

Flapless implant placement should be approached with caution. Primary stability is essential for success. The necessity of having an intact labial plate of bone before implant placement and elimination of any socket pathology are essential factors before implant placement, for achieving a predictably successful esthetic implant restoration. Flapless implant surgery is a difficult clinical procedure that entails many technique-sensitive details and treatment skills. It is advised to consider this technique with caution and to apply the recommended treatment protocol.

Treatment

The treatment plan included a strategy focussed on improving the osseous and soft-tissue volume. Flap exposure of the defect revealed a combination horizontal and vertical bone defect (Fig. 4). A corticocancellous graft was harvested from the symphysis area to augment the horizontal osseous deficiency (6) (Fig. 5). The recipient site was thoroughly débrided, curetted, and decorticated, and the graft then was stabilized with two microtitanium screws (Martin Micro Screw; Gebrüder Martin, Tuttlingen, Germany) (Fig. 6). A collagen membrane was used to cover the graft (Biomend; Zimmer Dental, Carlsbad, CA, USA). A pedicle subepithelial connective tissue graft was then harvested and rotated from the palate and sutured (Trofilene, Stoma®; Storz am Markt, Emmingen-Liptingen, Germany) to the labial periosteum. The purpose of this graft was to improve the quality and quantity of the labial soft tissues and to achieve socket closure coronal to the osseous graft at the socket orifice (Figs 7, 8).

Ten days postsurgery sutures were removed and tissue healing continued uneventfully (Fig. 9). Four months later, implant placement surgery was planned, via a single crestal incision that exposed the crest of the bone without reflecting the papillae (Fig. 10). Further tissue reflection was not performed in order to reduce postsurgical tissue recession (Fig. 11). A 3.8 × 13 mm BioHorizons implant (Laserlock; BioHorizons, Birmingham, AL, USA)

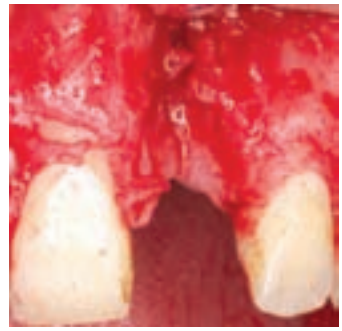


Fig. 4 Intraoperative view of the defect showing extensive tissue loss and granulation tissues.

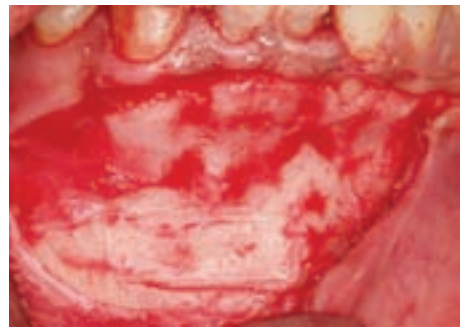


Fig. 5 Intraoperative view of the outline osteotomy of the chin graft (donor site).

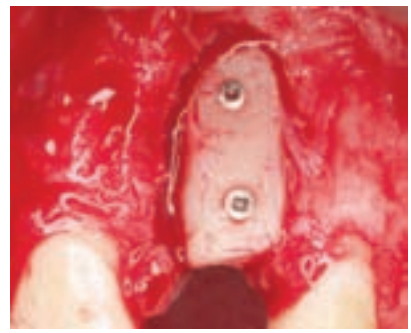


Fig. 6 Chin graft stabilized in place to restore the osseous defect with two microtitanium screws.

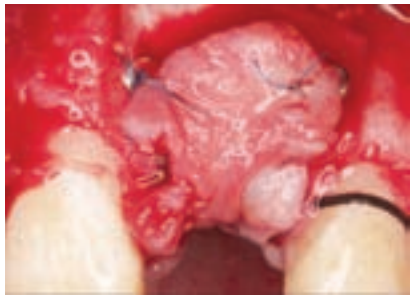


Fig. 7 Pedicle connective tissue graft from the palate to ensure optimal wound closure, minimize the possibility of graft exposure, and enhance the labial topography.

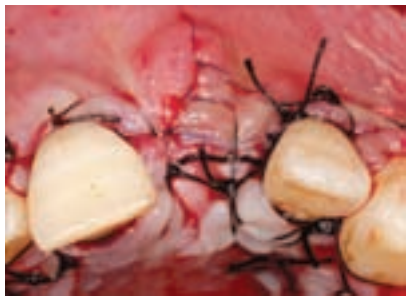


Fig. 8 Soft-tissue closure at the time of surgery.

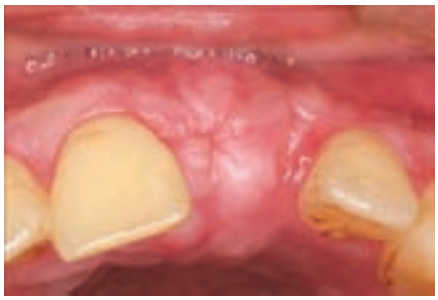


Fig. 9 Image 3 weeks posthealing showing optimal soft-tissue closure and enhanced soft-tissue status.

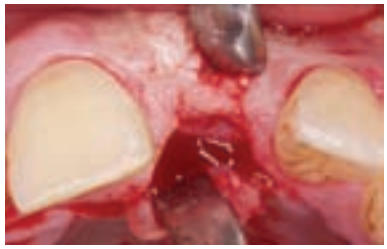


Fig. 10 Intraoperative view of the grafted bone 4 months after surgery showing new bone formation.

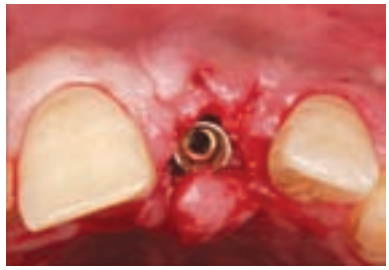


Fig. 11 Implant fixture placed: incisal view. Note the minimally invasive flap design and the papillary enhancement technique (split finger technique).

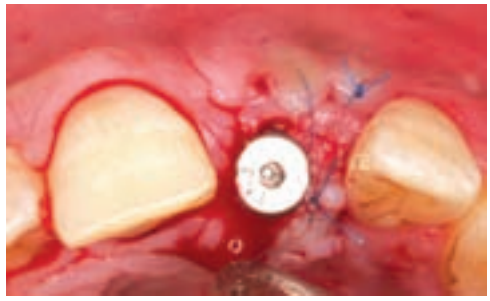


Fig. 12 Case sutured.

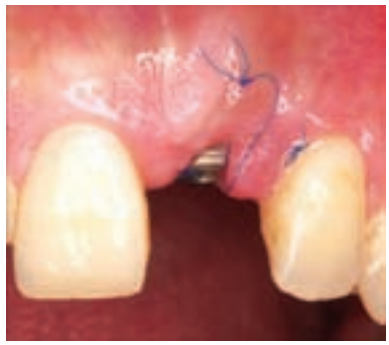


Fig. 13 One week posthealing: labial view showing the clinical outcome of the split-flap technique.

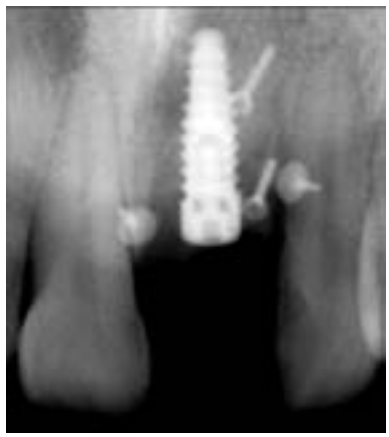


Fig. 14 Periapical view showing the implant in place.

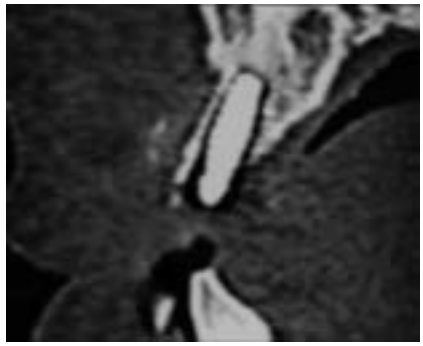


Fig. 15 CAT view showing the labial bone covering the implant site.

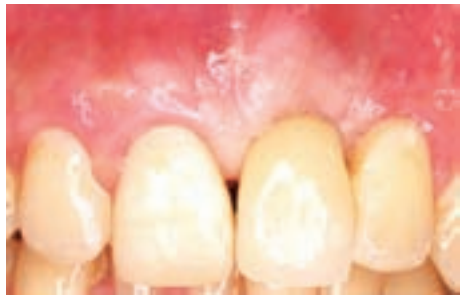


Fig. 16 The case finally restored.

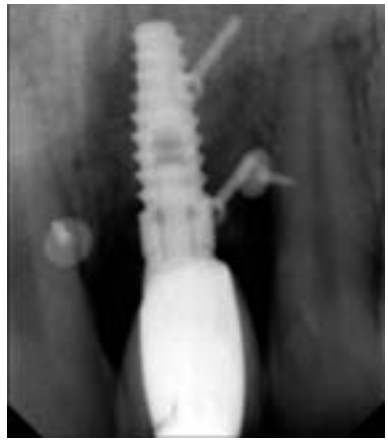


Fig. 17 Radiographic view showing the case restored.

(Fig. 12) was placed. The patient was given a tooth-borne removable partial denture to use whenever needed.

A split-fingered technique was performed at the time of implant placement to allow papillary level enhancement of the left papilla (Fig. 13) and augment the soft tissue of the peri-implant papilla. This procedure has shown high predictability and clinical efficiency. The technique entails reflecting a palatal flap at the time of implant surgery and splitting it into two halves, then suturing each half to the closest labial flap (7). A periapical radiograph was taken to confirm the proper implant position (Fig. 14). A CAT scan was then taken to validate the amount of new regenerated bone and determine that the implant had an adequate buccal plate of bone (Fig. 15). Following tissue healing, a porcelain fused to metal final restoration was cemented (Ketac Cem; 3M ESPE, Seefeld, Germany) (Fig. 16). A periapical radiograph taken after completion of the restoration shows the implant to be well positioned regarding the surrounding bone and adjacent teeth (Fig. 17).

References

1. Campelo L, Camara J. Flapless implant surgery: a 10-year retrospective analysis. *Int J Oral Maxillofac Implants* 2002; **17**: 271–6.
2. Pow E, McMillan. A modified implant healing abutment to optimize soft tissue contours: a case report. *Implant Dent* 2004; **13**: 297–300.
3. El Askary AS. Multifaceted aspects of implant esthetics: the anterior maxilla. *Implant Dent* 2001; **10**: 182–91.
4. El Askary AS, Meffert RM, Griffin T. Why do dental implants fail? Part I. *Implant Dent* 1999; **8**: 173–85.
5. El Askary AS, Meffert RM, Griffin T. Why do dental implants fail? Part II. *Implant Dent* 1999; **8**: 265–77.
6. Schwartz-Arad D, Levin L. Multitier technique for bone augmentation using intraoral autogenous bone blocks. *Implant Dent* 2007; **16**: 5–12.
7. Misch CE, Al shammari.K, Wang HL. Creation of interimplant papillae through a split-finger technique. *Implant Dent* 2004; **13**: 20–7.

Case 7: Treatment and replacement of a malpositioned implant in the esthetic zone

Scott H. Froum DDS

A 24-year-old woman with a non-contributory medical history, taking no medications, and with no known food or drug allergies, presented with a chief complaint that "I do not like the look of my front tooth and I can no longer smile because I have a long front tooth" (Fig. 1). Because

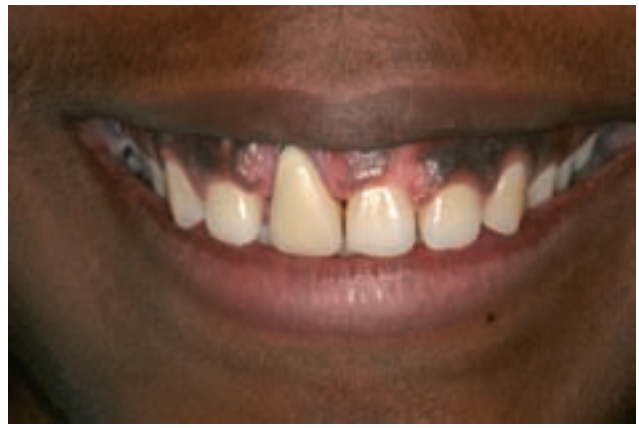
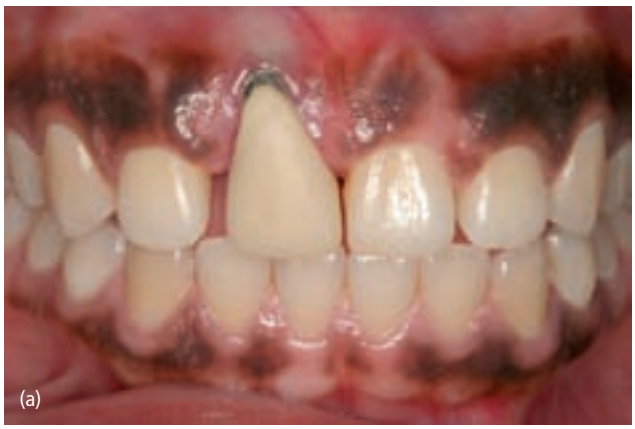


Fig. 1 Preoperative view showing asymmetric right central incisor length and a high smile line.

the patient was a medical nurse and familiar with healthcare documentation, her recall of prior dental treatment was detailed. The patient was told 2.5 years ago that tooth no. 8 was hopeless owing to a failed root canal and fractured post. Implant therapy was recommended and, according to the patient, "I was told that the tooth could be taken out and the implant could be placed on the same day." The tooth was extracted and an implant was placed immediately. The patient was temporized with a removable provisional. About "1 year later" the patient had stage 2 uncovering performed and "I was given a temporary tooth the day I had my implant exposed". The patient recalled that at the time she received this temporary crown, she complained that the tooth looked "too long" but was told by the dentist that it "was only a temporary and could be fixed". A few months later the patient developed recurrent abscesses in the area of her implant and was given a series of antibiotics. The patient presented to my office after months of episodic abscess formation with no treatment rendered since her previous dentist had since closed his office because of a fire and was no longer treating patients.

A clinical examination revealed a malpositioned implant in site 8 with a platform emergence at a 45-degree angle to the buccal ridge. In addition diastemas were present between crown numbers 7 and 8, and 8 and 9. The implant was provisionalized with an angulated abutment that had been modified to compensate for implant malposition (Fig. 2a, b). Clinical examination revealed a midbuccal probing depth of 10 mm with bleeding on light probing. Radiographic computed tomographic (CT) scan examination showed that her previous dentist had used a 5 × 16 mm implant of which 12 mm was dehisced through the buccal plate (Fig. 3). This was later verified clinically during surgery. The case was even more complicated since the patient had a high smile line.



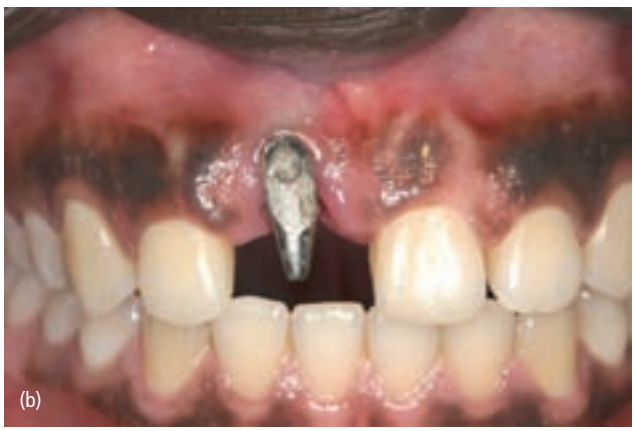


Fig. 2 (a) Preoperative clinical views of unesthetic implant 8 restoration. (b) Image showing the poor position of the abutment.

Etiology

The complication seen in this case was related to the incorrect placement of the dental implant. The implant was placed 7 mm apical to the cementoenamel junction of the adjacent tooth with a 45-degree implant platform emergence to the buccal crest requiring the provisional restoration to extend apical to the adjacent teeth. As a result of placement position, 12 mm of the implant surface had dehisced through the buccal plate, resulting in recurrent abscess formation.

Prevention

This complication could have been prevented by correct three-dimensional (3D) positioning of the dental implant. The implant was placed immediately after the extraction of the tooth without the use of a 3D radiograph (the patient reported that she never had a CT or cone beam scan before her implant treatment) or a surgical guide. After tooth extraction, if the implant surgeon cannot obtain primary stability in an ideal implant position the implant should not be placed. Instead, the area should be augmented and implant placement delayed. In addi-

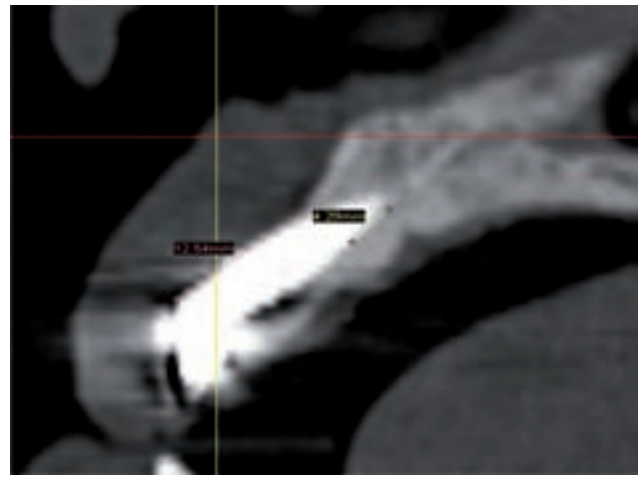


Fig. 3 Preoperative CT scan showing 12 mm of the implant devoid of buccal bone.

tion, if the implant is placed incorrectly, it should be removed at the time of placement and should be either redirected or placed with a delayed protocol after healing.

Treatment

The patient was informed that the implant was hopeless and needed to be removed. The patient was given the option of replacement via a removable partial denture, a fixed partial denture or augmentation and placement of another implant. The patient chose the latter option as she "wanted to have an implant from the start" and did not want anything removable. The patient was informed that after extraction of her implant she would need multiple surgeries to repair the area which may or may not have yielded a site amenable to implant placement. She was also informed that to achieve the esthetic result she desired would require restorations (laminate veneers), at minimum, on teeth numbers 7, 9, and 10. The patient consented to the treatment plan.

Before her surgical appointment impressions were taken and a ceramometal resin-bonded (Maryland) bridge was fabricated to function as a provisional after implant extraction to avoid placing pressure on the augmented area. One day before the implant removal surgery, the patient started methylpredrisone (Medrol Dose pack; MOVA Pharmaceuticals, Manati, PR, USA) and rinsing with chlorohexidine gluconate 0.12% twice daily (Peridex; ESPE 3m, St Paul, MN, USA). On the day of the implant removal surgery, the patient was premedicated with 2 g amoxicillin followed by 500 mg taken three times a day for the following 10 days.

Surgery consisted of a midcrestal incision with papilla-sparring vertical releasing incisions on the distal aspects of teeth 7 and 10. A full-thickness mucoperiosteal flap was elevated, the area was débrided, and granulation tissue was removed, demonstrating that over 75% of the implant body had buccally fenestrated (Fig. 4). A piezoelectric surgical unit (Mectron) was used with copious irrigation to remove the implant as atraumatically as possible (Fig. 5). The implant was removed *en bloc*, which resulted in a 12 × 7 × 20 mm ridge defect (Fig. 6). The area was grafted with anorganic bovine bone and collagen (Bio-Oss collagen; Osteohealth Shirley, NY, USA) (Fig. 7) and then covered with beta-tricalcium phosphate (B-TCP)

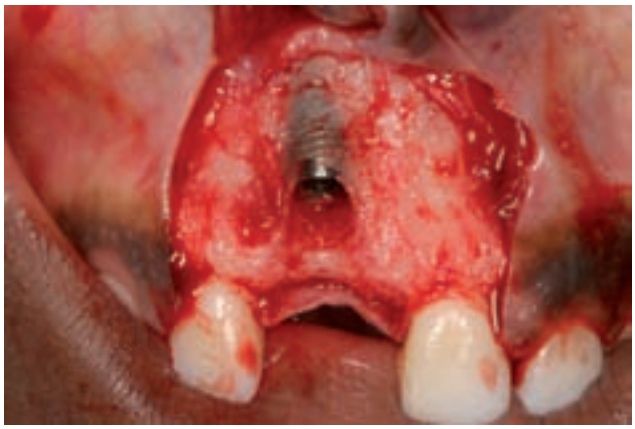


Fig. 4 Clinical photograph showing the buccal implant dehiscence after flap reflection.

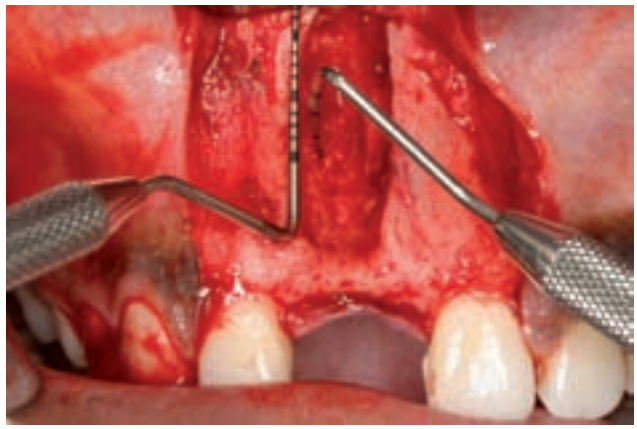


Fig. 6 The 15 × 20 mm residual defect left after implant removal.

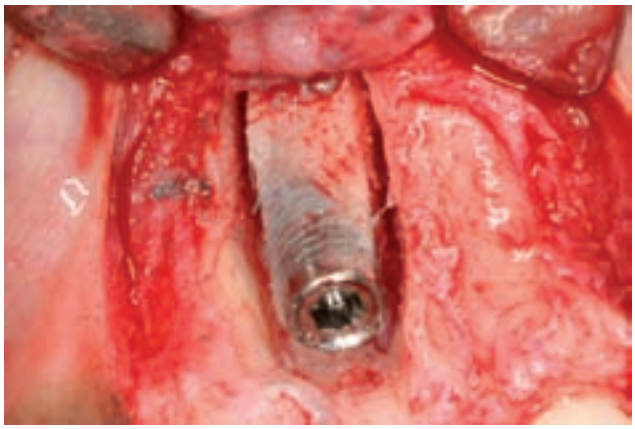


Fig. 5 Implant removal with piezoelectric surgery.

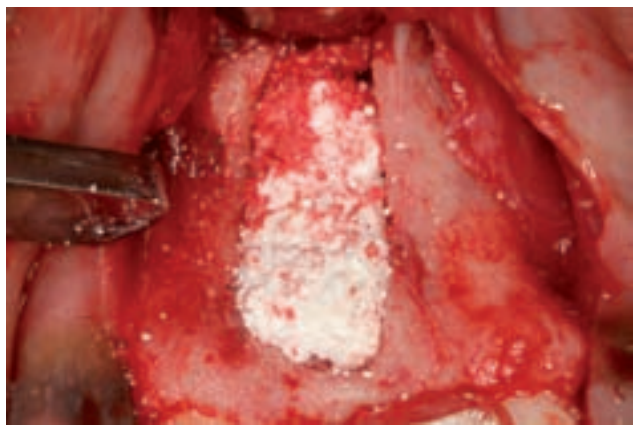


Fig. 7 Anorganic bovine bone placed in the defect.

and platelet-derived growth factor (PDGF) (Gem 21; Osteohealth, Shirley, NY, USA) (Fig. 8). The primary graft material was used for its ability to maintain structural support and the secondary graft material for its qualities of enhancing soft-tissue healing and recruitment of osteogenic precursors. A 30 × 40 mm porcine collagen membrane (Ossix Plus, Orapharma, Warminster, PA) was then placed over the defect and stabilized with two stainless steel tacks (BioHorizons, Birmingham, AL, USA) (Fig. 9). Periosteal releasing incisions were made to allow tension-free closure, but primary closure was intentionally not attempted and the membrane was left exposed so as to not create a mucogingival defect. The vertical incisions were closed with 4.0 chromic gut in single interrupted fashion (Ethicon, J&J, Somerville, NJ, USA) and the midcrestal incision was closed with non-absorbable sutures in continuous horizontal mattress fashion (Gortex; W.L. Gore Associates, Flagstaff, AZ, USA) (Fig. 10). Peri-acrylic was then placed over the vertical incisions (Glue Stitch, British Columbia, Canada). The area was temporized by etching and bonding the fabricated Maryland bridge to the adjacent teeth. Careful attention was paid to adjusting the temporary and relieving tissue pressure (Fig. 11). The patient was given post-operative instructions and was seen routinely for follow-up. Healing was uneventful and the provisional bridge was cut back at 5 months to reveal a deficiency in bony and soft-tissue thickness (Fig. 12).

Six months after the original implant was removed the patient was sent for a CAT scan, and impressions were taken to generate a diagnostic wax-up. The treatment plan included placing porcelain veneers on teeth numbers 7, 9, and 10 and an implant crown on tooth 8. Prosthetic restoration was planned on these teeth to compensate for the mesial–distal discrepancy between implant 8 and tooth 9. CT scan analysis showed a well-developed ridge and using CT scan software (Simplant 11.0; Materialise, Glen Burnie, MD, USA) a 3.5 × 13 mm implant was planned for placement.

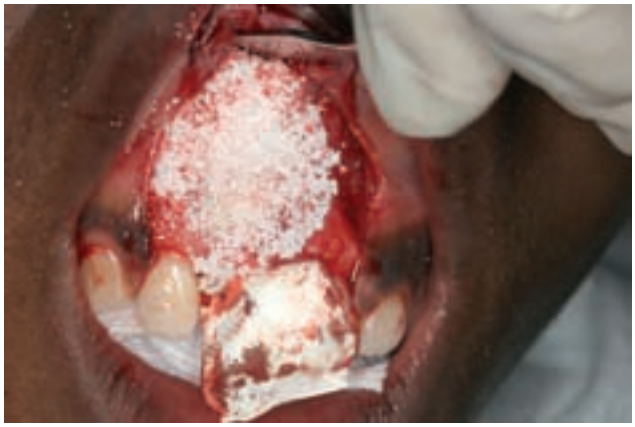


Fig. 8 B-TCP and PDGF Layered over the primary graft material.

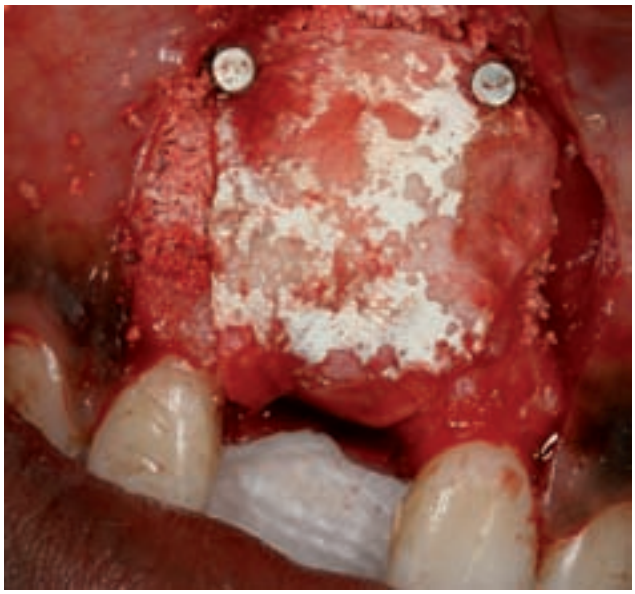


Fig. 9 A 30 × 40 mm porcine absorbable membrane covering the graft and stabilized with two stainless steel tacks.

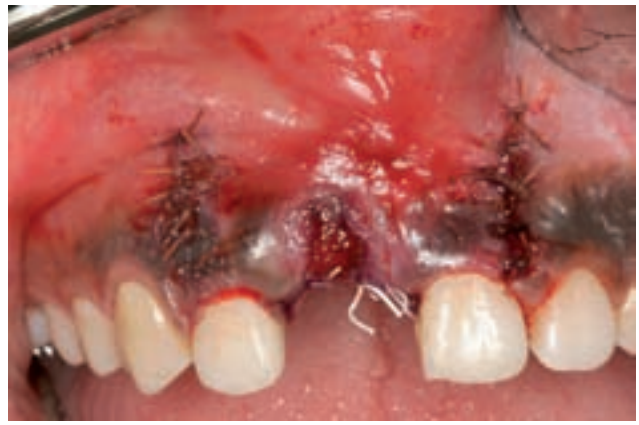


Fig. 10 Tension-free flap closure. The membrane was intentionally left exposed.

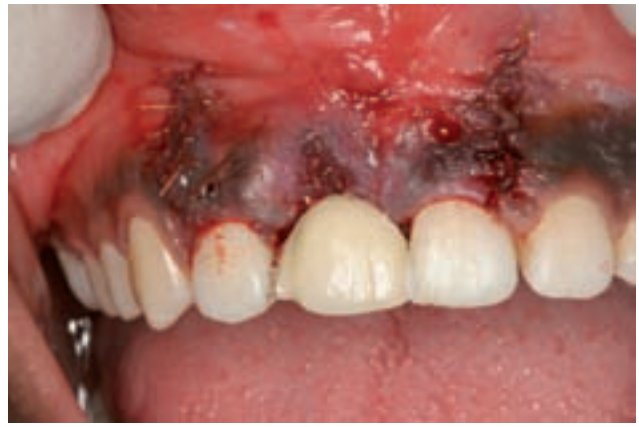


Fig. 11 Temporization with a fixed resin bonded bridge adjusted to avoid soft-tissue pressure.

On the day of implant surgery, the patient was premedicated with the same medications previously described. Following the same incision lines, a papilla-sparring full-thickness flap was elevated. Complete bony fill of the original defect was observed (Fig. 13) with 6 mm of ridge width existing at the alveolar crest (Fig. 14). During implant placement an anatomically correct surgical guide was used to create the implant osteotomies and a 3.5 × 13 mm straight implant (Neoss Bimodal, Burbank, CA, USA) was placed with good primary stability using the guide (Fig. 15). Because of a thin buccal plate as well as a pre-existing bony and soft-tissue deficiency, the area was simultaneously augmented with B-TCP and PDGF (Fig. 16). A split-thickness flap was elevated and a 30 × 40 porcine membrane (Ossix; Orapharma, Warminster, PA, USA) was placed over the graft material for containment and stabilized with 4.0 chromic sutures in single interrupted fashion, which engaged the buccal periosteum and lingual flap (Fig. 17). The flaps were advanced and primary closure was achieved with 4.0 chromic gut with single interrupted sutures (Fig. 18). Implant position was verified with a periapical radiograph (Fig. 19). The patient's resin-bonded bridge was further adjusted and the area was again temporized.

The same postoperative instructions and follow-up protocols were followed as described previously and the implant was allowed to heal for 6 months. Healing was uneventful and 6 months after placement adequate soft-

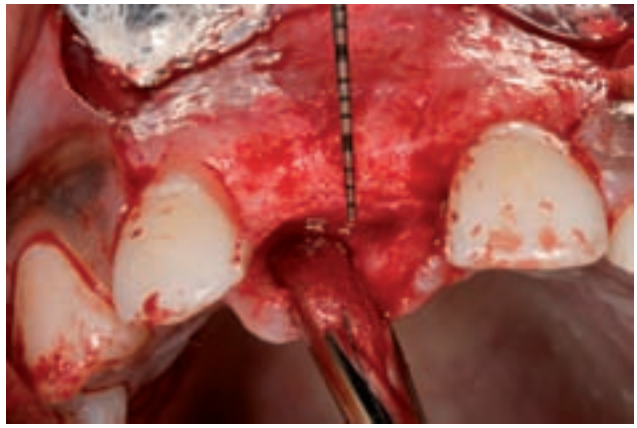


Fig. 14 Six millimeters of ridge width at the alveolar crest.

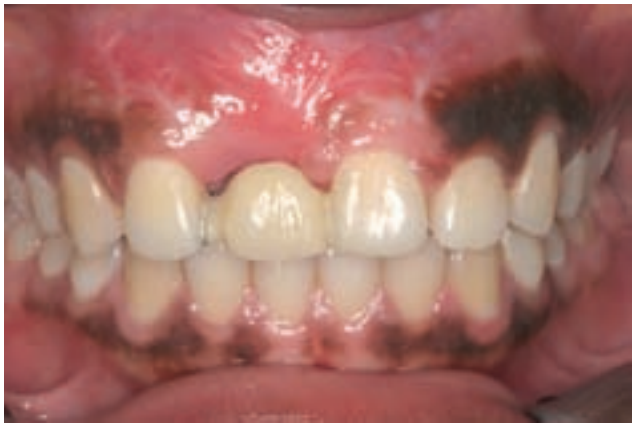


Fig. 12 Clinical photograph demonstrating uneventful healing at 5 months with soft-tissue and bone shrinkage.

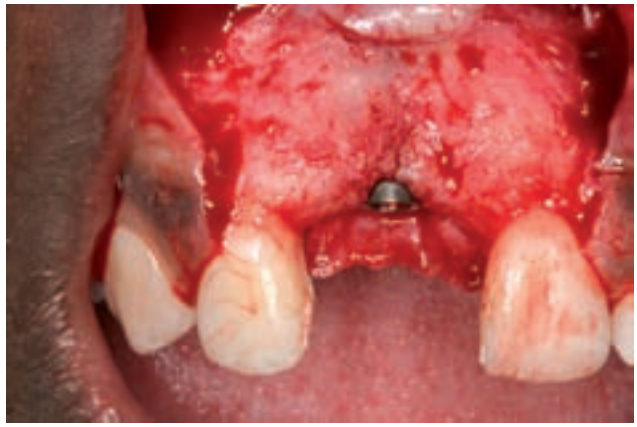


Fig. 15 Proper three-dimensional placement of the dental implant.

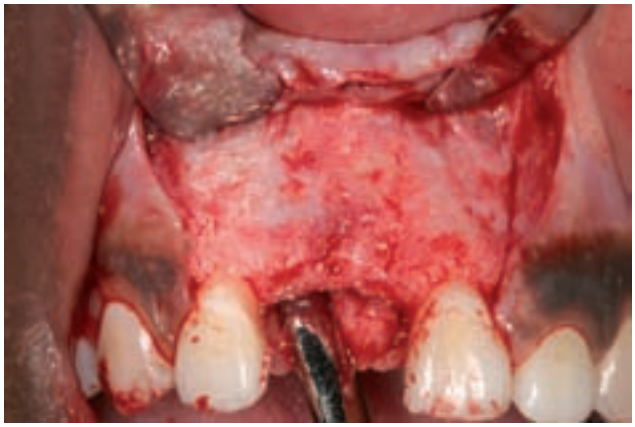


Fig. 13 Flap reflection revealing complete bony fill of the defect.

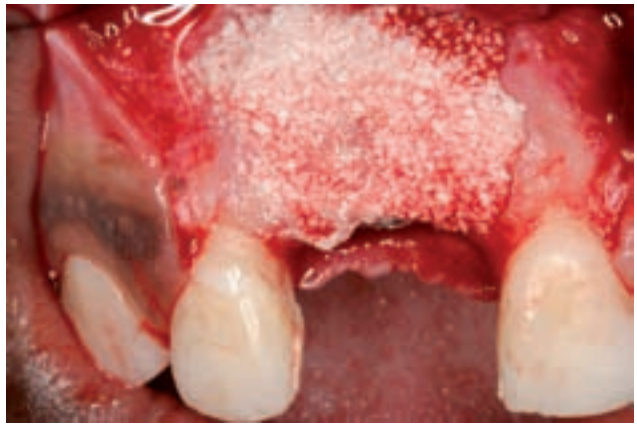


Fig. 16 Additional augmentation after implant placement with B-TCP and PDGF.

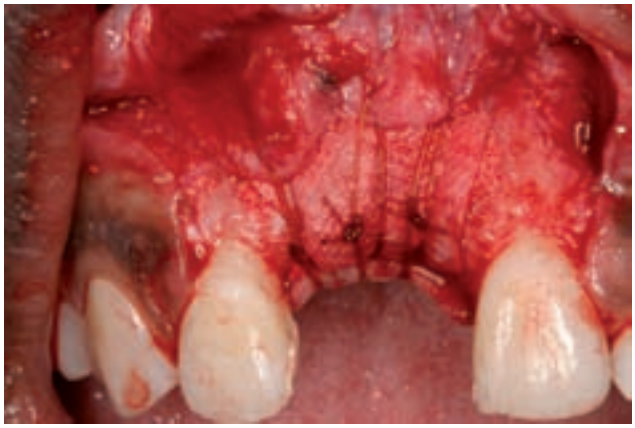


Fig. 17 Porcine absorbable collagen membrane placed over graft material and stabilized with 4.0 chromic gut sutures.

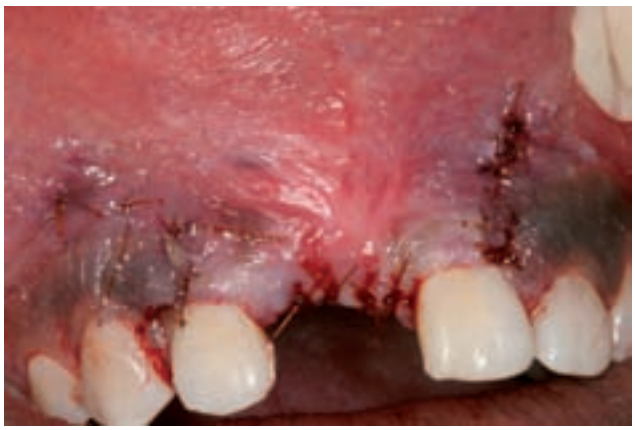


Fig. 18 Tension-free primary closure after implant placement.

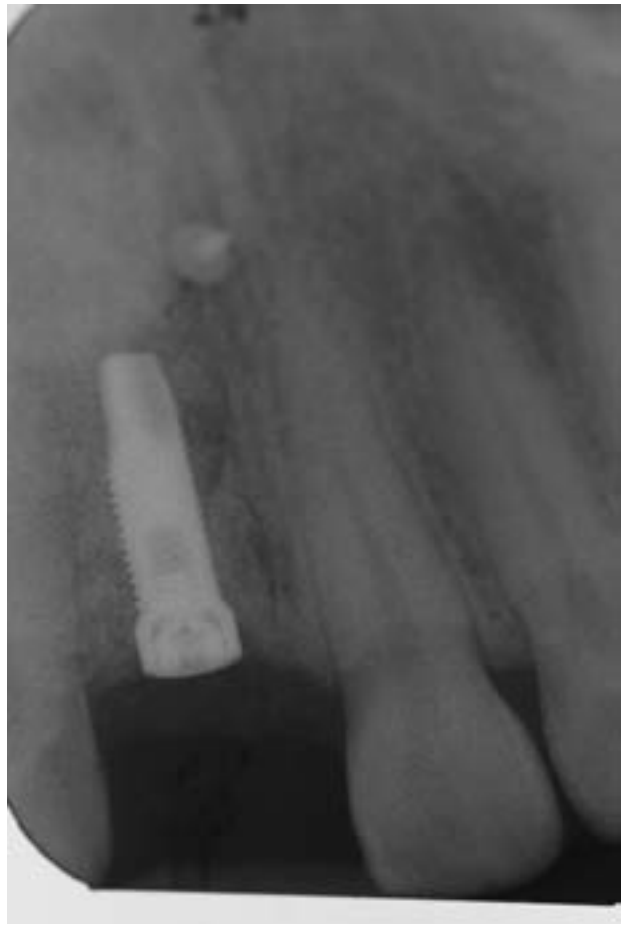


Fig. 19 Periapical radiograph after implant placement.

tissue and bone volume was present, as verified clinically (Fig. 20) and radiographically (Fig. 21).

At this time stage 2 was performed by making a midcrestal incision with papilla-sparring vertical release incisions. A full-thickness flap was raised, exposing the implant and demonstrating adequate bone fill and an adequate buccal plate (Fig. 22). At the time of stage 2 surgery, the implant was provisionalized with an anatomically correct PEEK esthetic abutment (Neoss Anatomic abutment, Burbank, CA, USA) (Fig. 23). A rubber dam was placed and the provisional abutment was prepared (Fig. 24). Using flowable temporization material (ProTemp Plus; ESPE 3m, St Paul, MN, USA) and a vacuform guide created from the diagnostic wax-up, a temporary abutment was created and the flaps were sutured with 4.0 chromic gut in single interrupted fashion (Fig. 25). The temporary was placed in order to begin to develop soft-tissue emergence after stage 2 surgery.

The area was allowed to heal (Fig. 26) and 2 months later crown lengthening surgery was performed on the adjacent teeth 6–11 (Fig. 27) using the diagnostic wax-up as a surgical guide. The area was allowed to heal for 3 months and the teeth were prepared for veneers on

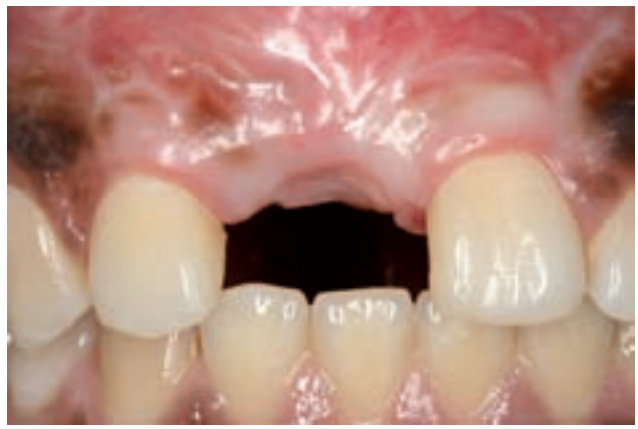


Fig. 20 Six months after implant placement adequate soft-tissue and bone volume had been achieved.

nos 7, 9, and 10. A custom abutment and an all-porcelain crown were used to restore the implant in site 8 (Fig. 28) (Marotta Dental Studio, Melville, NY, USA). All prosthetic work was completed by Dr Christopher Salierno (private practice, Huntington, NY, USA). The patient was given homecare instructions and has been seen every 3 months for maintenance.

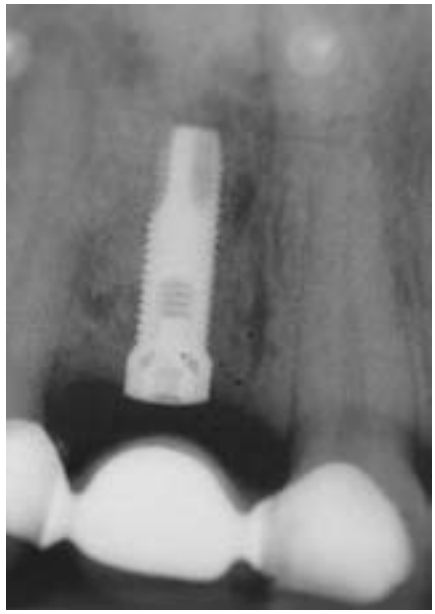


Fig. 21 Periapical radiograph of implant 8, 6 months postplacement.

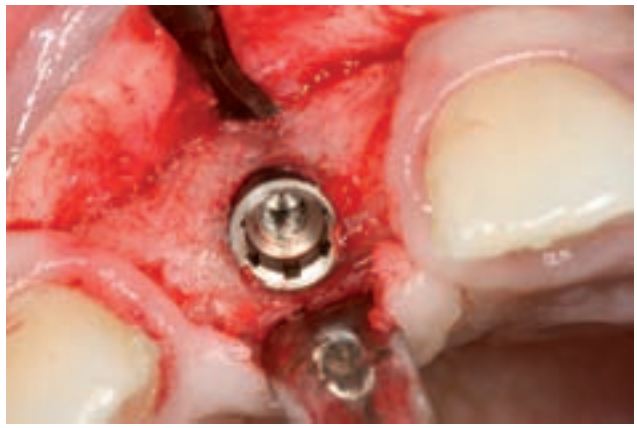


Fig. 22 Stage 2 uncovering implant demonstrating successful bony fill.

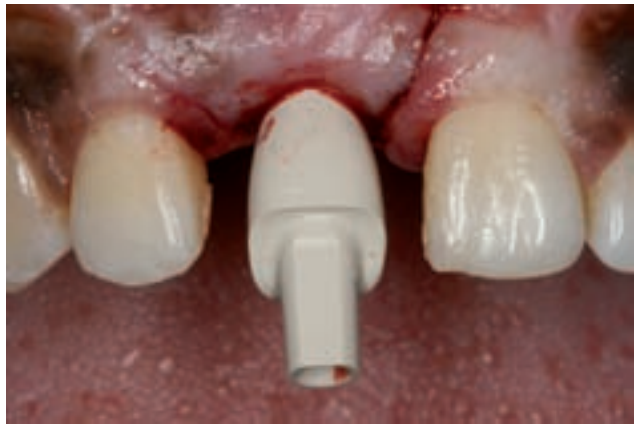


Fig. 23 PEEK anatomic temporary abutment placed at the time of stage 2 uncovering.

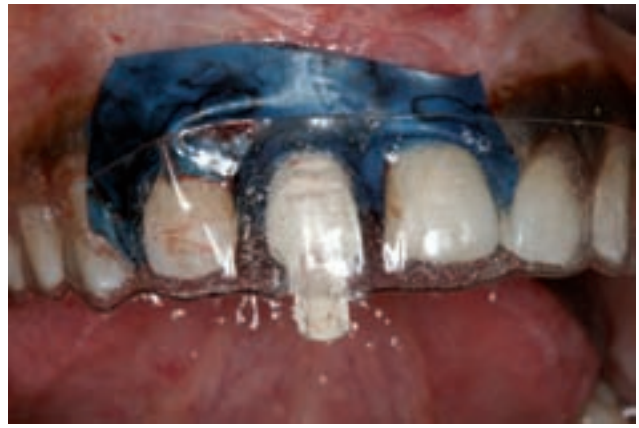


Fig. 24 PEEK anatomic temporary abutment with rubber dam and vacuform guide to create provisional crown.

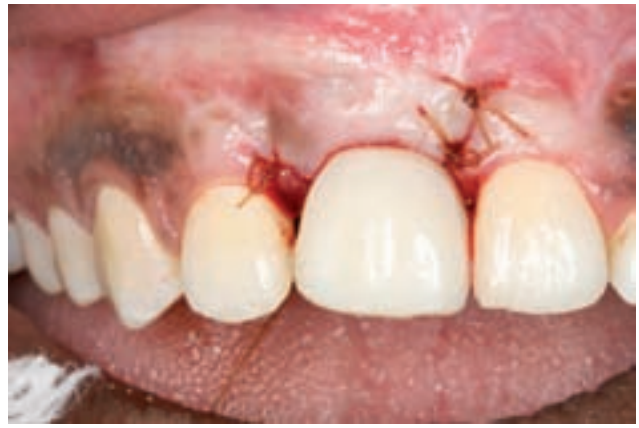


Fig. 25 Provisional crown restoration at the time of stage 2 surgery.

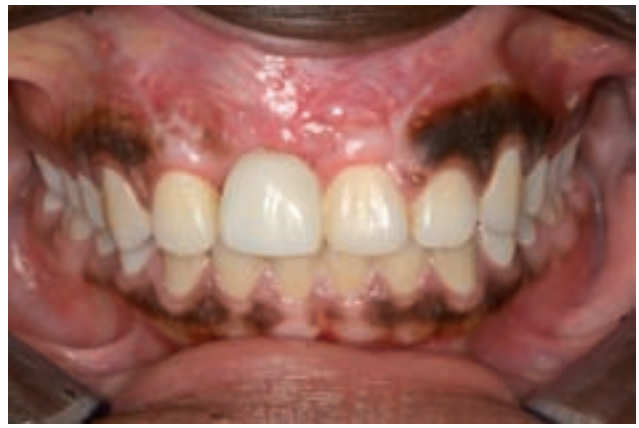


Fig. 26 Healing of the soft tissue around the provisional.

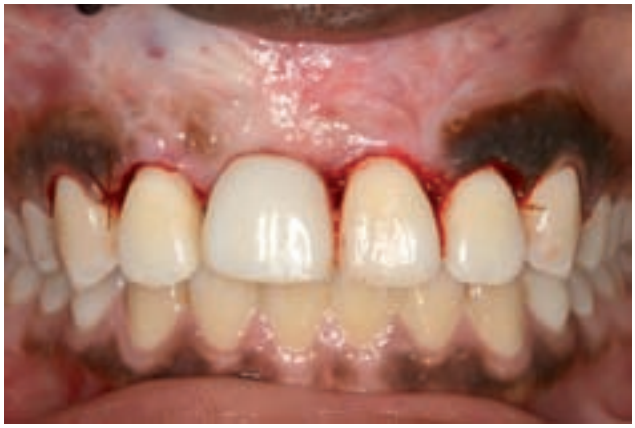


Fig. 27 Crown lengthening was performed for teeth numbers 6–11.

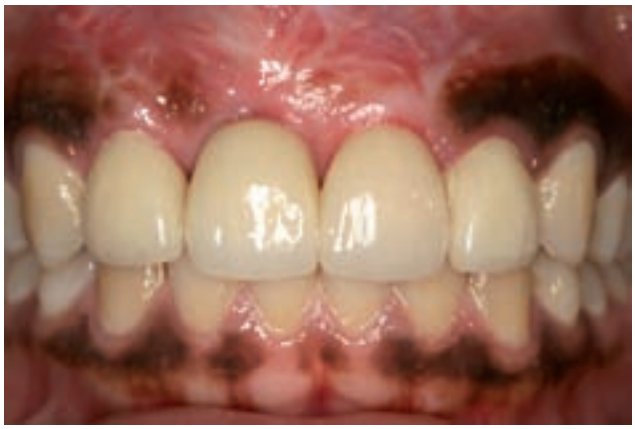


Fig. 28 Final prosthetic restoration.

Case 8: Corrective treatment for a malpositioned implant in the esthetic zone

J. Daulton Keith DDS, FACD, FICD

The patient was a 26-year-old woman, a high-school science teacher, who presented with the chief complaint of "I look like a rodent!" (Fig. 1a, b). Her medical history included hyperthyroidism, and severe allergy to sulfa drugs, and she "smokes occasionally".

A dental implant had been placed 1 year previously in the maxillary right central incisor site. The central incisor tooth had been lost owing to an endodontic root fracture. The loss of alveolar ridge height or width from tooth loss due to trauma, developmental anomalies, or pathology frequently can make implant placement difficult if not impossible when the goal is to restore esthetics and functional harmony.

Because of the extreme apical position of this implant and the patient's high smile line, a decision was made to remove the implant, repair the hard- and soft-tissue defect, and restore the site with another dental implant (Fig. 2).

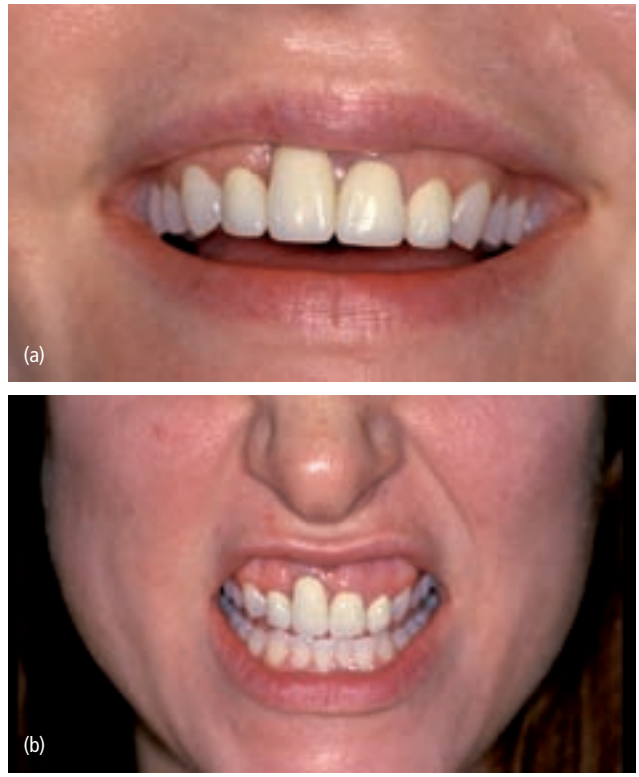


Fig. 1 (a) Clinical photograph of "long" maxillary right central incisor (no. 8) implant-supported crown: normal smile line. (b) Patient's exaggerated smile, showing unesthetic tooth 8 implant crown.

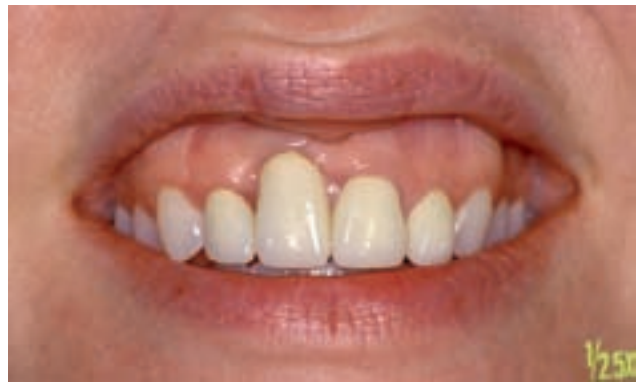


Fig. 2 Facial photograph of maxillary anterior soft-tissue contours.

Etiology

The esthetic and functional complications in this case were due to the extreme apical malposition of the dental implant. This resulted from inadequate hard- and soft-tissue volume and inadequate treatment planning. A dental implant should be placed no more the 2–3 mm apical to the gingival margin at the midfacial of the adjacent central incisor in order to achieve esthetic symmetry. This implant was 3 mm deeper than ideal (Fig. 3).

Prevention

The use of a surgical stent created from an ideal wax-up could have determined the ideal emergence profile and would have clearly identified the potential complications with this case before surgical intervention.

Treatment

The patient was informed that the esthetic correction of the problem with the existing implant and crown replacing her maxillary right central incisor was not possible and the implant would have to be surgically removed. She was also informed that restoration of this area to normal esthetic and functional health would require multiple surgical intervention procedures.

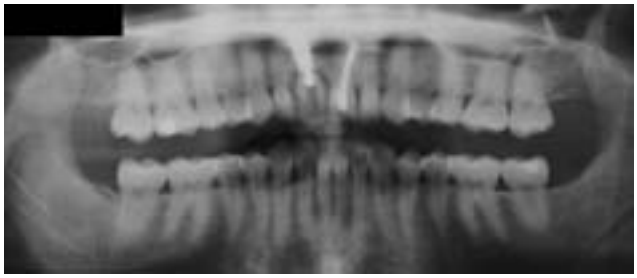


Fig. 3 Panoramic radiograph showing malpositioned implant 8, inserted too far apically.

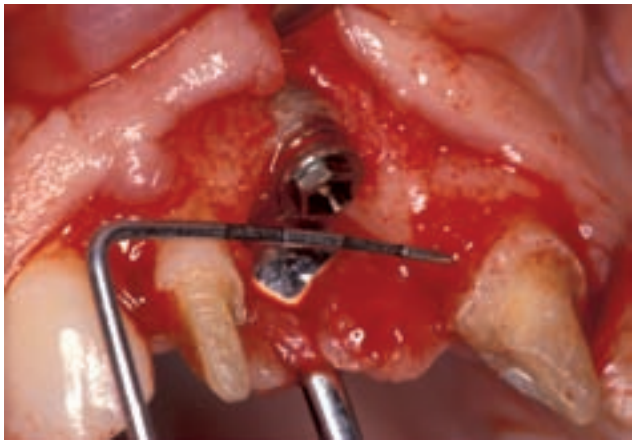


Fig. 4 Clinical photograph showing apical position of no. 8 implant.

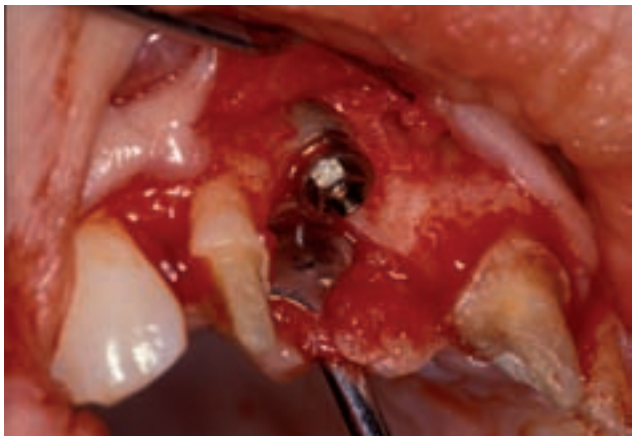


Fig. 5 Clinical photograph showing apical position and facial bone loss on no. 8 implant.

Surgery I

The completely integrated implant was removed by surgically releasing the labial tissue with a full-thickness flap (Fig. 4). A 2–3 mm mesial and distal cut was made into the facial alveolar bone directly adjacent to the implant body using a high-speed Kavo handpiece with a FG-701SL carbide bur (Fig. 5). A Lux-3 straight oral elevator was used to mobilize and separate the implant from the surrounding bone. Once the initial integration was broken the implant was backed out of the surgical site (Fig. 6). After the minimally traumatic (see existing threads in fill bone) removal of the implant, mineralized cortical bone (250-900) (Puros; Zimmer, Carlsbad, CA, USA) was placed into the extraction site and a resorbable collagen membrane (Bio-Gide; Osteohealth, Shirley, NY, USA) was placed to repair the extraction site (Fig. 7). The

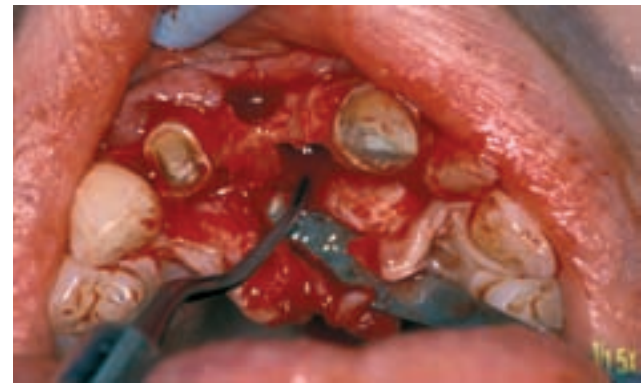


Fig. 6 Photograph demonstrating large incisive palatine foramen and 2 mm buccal crest width after implant removal.

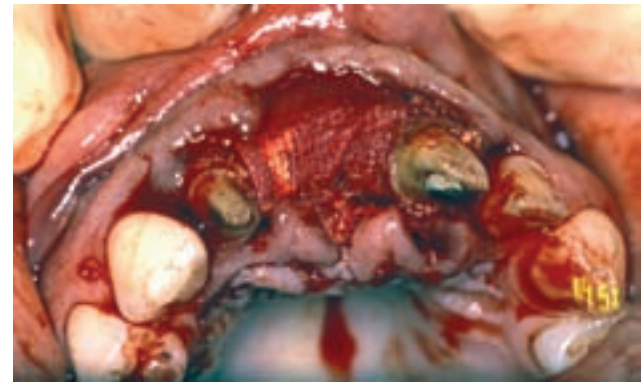


Fig. 7 Mineralized cortical particulate allograft in place and covered with a resorbable collagen membrane (Bio-Gide) to augment the ridge.

surgical site was closed primarily and sutured with 4.0 Vicryl sutures (Ethicon, Somerville, NJ, USA).

Surgery II

After 4 months of healing for the particulate bone graft, a second surgical procedure was necessary to enhance the vertical bone height (Fig. 8).

A full-thickness mucoperiosteal flap was reflected and the alveolar bone was recontoured to create an acceptable receptor site for a block allograft (Fig. 9). A block allograft (Puros; Zimmer) was placed and secured with two 1.5 × 12 mm lag screws (KLS Martin LP, Jacksonville, FL, USA) (Fig. 10). Additional particulate mineralized cortical bone was mixed with tetracycline and placed on the labial aspect of the block graft (Fig. 11). Theoretically, adding tetracycline renders the particulate graft material more osteoinductive. The entire graft site was then covered with a resorbable collagen membrane (Bio-Gide) (Fig. 12). The surgical site was closed with a combination 4.0 gut sutures (Ethicon, Somerville, NJ, USA) for the vertical releasing incision and 4.0 Gor-tex suture (W.L.

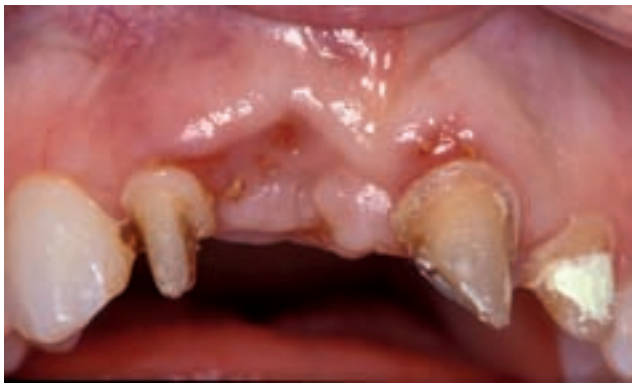


Fig. 8 Healed ridge 4 months after implant removal surgery.

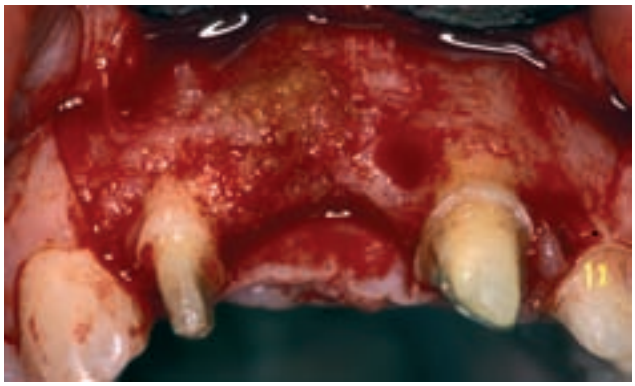


Fig. 9 Flap reflected, showing implant extraction site 4 months after removal and ridge augmentation.

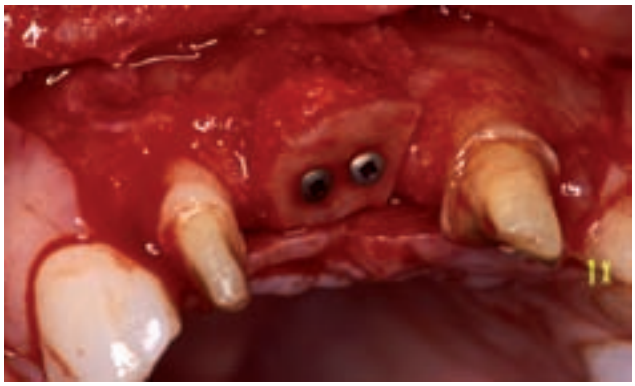


Fig. 10 Second surgical procedure to increase the vertical osseous height with an allograft block (Puros).

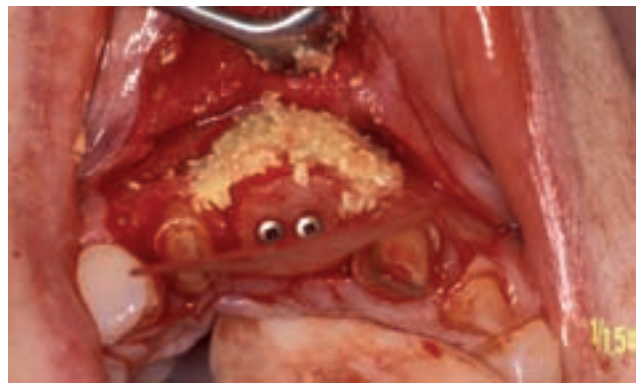


Fig. 11 Particulate allograft bone mixed with tetracycline placed on the labial aspect of the block graft.

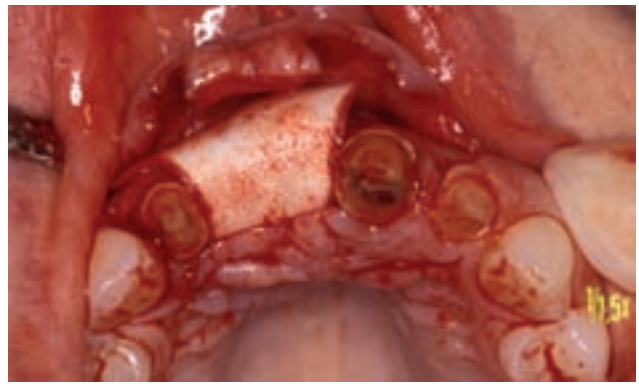


Fig. 12 Resorbable collagen membrane (Bio-Gide) in place.

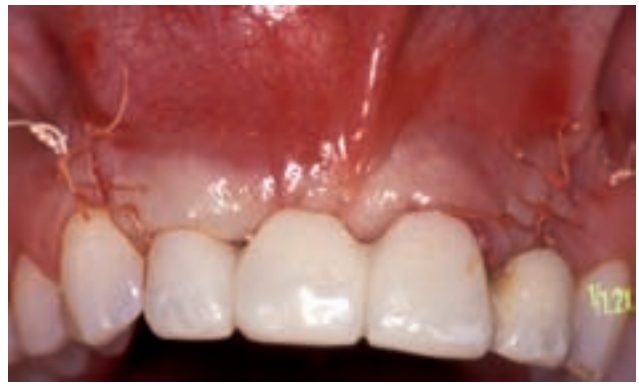


Fig. 13 Primary closure following block allograft with provisional in place.

Gore Associates, Dundee, UK) for primary flap closure (Fig. 13). The block allograft was allowed to heal for 6 months before implant placement (Fig. 14). After 6 months of healing, and using a surgical stent to mimic the emergence profile of the maxillary left central, a 4.7 mm diameter tapered screw vent implant (Zimmer) was placed (Figs 15–21). The implant was allowed to heal for 6 months owing to the significant amounts of osseous grafting that had been necessary to restore this site.

After 6 months the implant was exposed and an immediate temporary abutment with an acrylic temporary crown was placed (Figs 22–26).

Six weeks after the implant was exposed (due to the patient moving) a final impression was taken and four individual Empress crowns were placed (Figs 27, 28). The crowns were constructed by Henry Martin (CDT at Restorative Arts Dental Lab, Charleston, SC, USA). All prosthetic procedures were performed by Dr James Rivers (Professor and Department Chair of Oral Rehabilitation, College of Dental Medicine, Medical University of South Carolina).

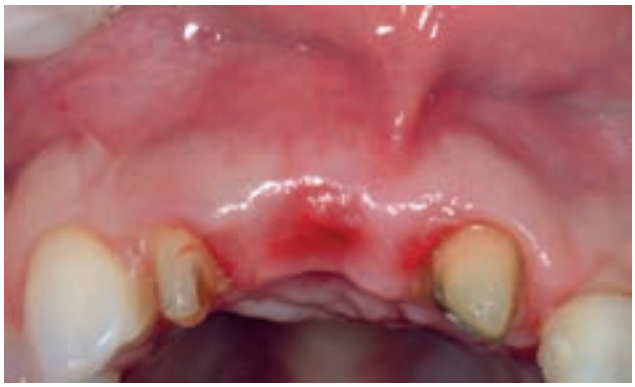


Fig. 14 Healing site 6 months after the block graft.

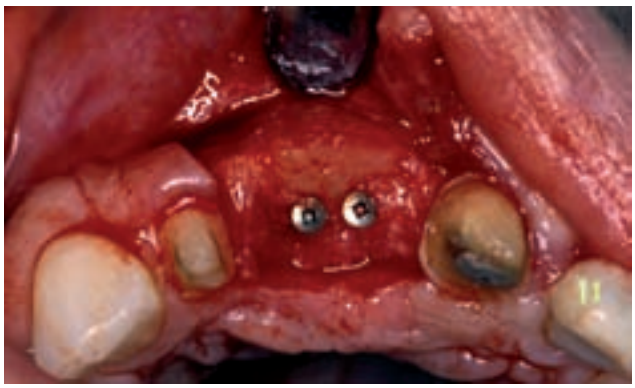


Fig. 15 Block allograft exposed for screw removal and implant placement.

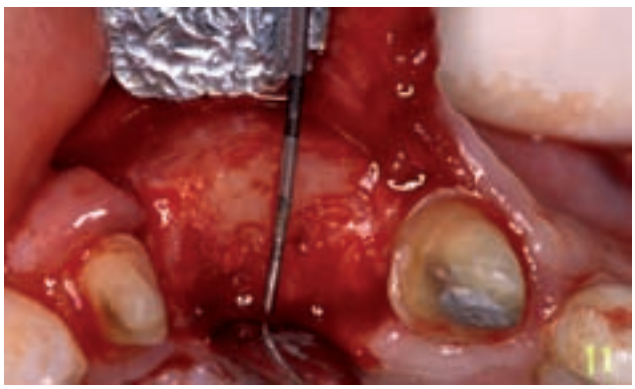


Fig. 16 Periodontal probe in place documenting augmented ridge width of 8–9 mm.

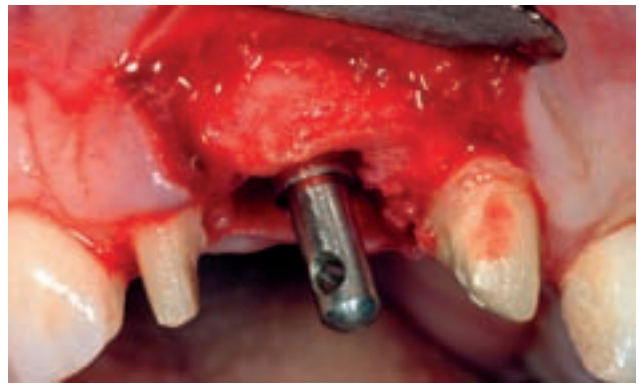


Fig. 17 Guide pin in place to evaluate emergence profile.

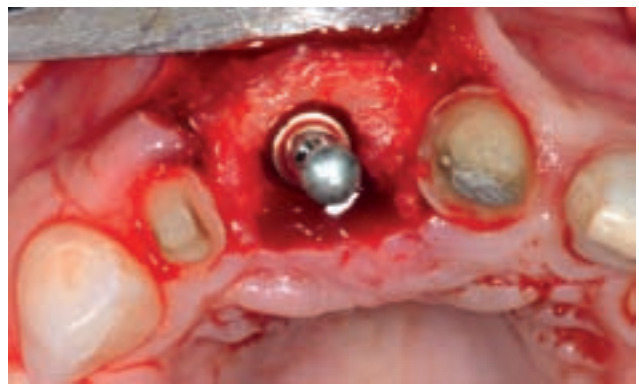


Fig. 18 Occlusal view of guide pin to verify buccolingual placement position.

Fig. 19 Tapered 4.7 mm diameter screw vent implant.

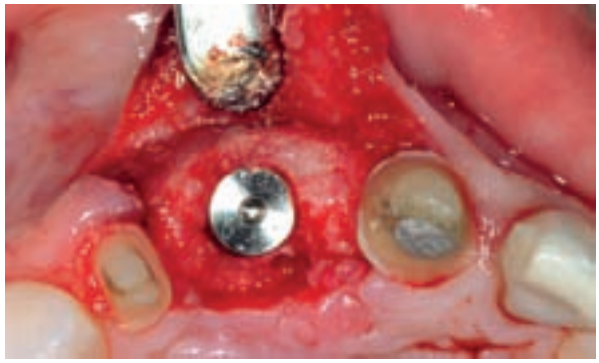


Fig. 20 Implant in place following guide pin position.

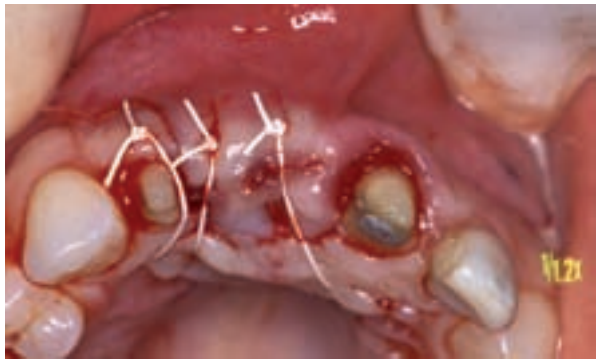


Fig. 21 Non-absorbable sutures for flap closure.

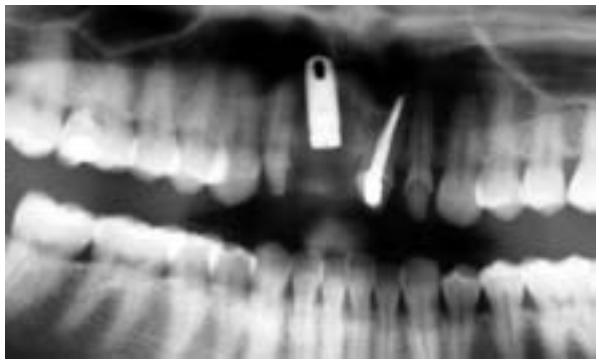


Fig. 22 Panoramic radiograph of 4.7 × 13 mm implant in place. Note the mesial angulation of tooth 9.

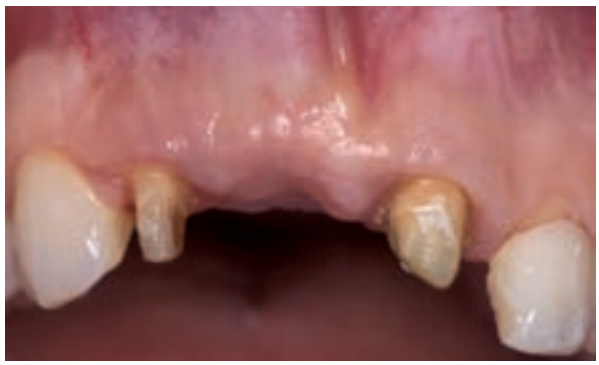


Fig. 23 Postoperative photograph of healing, 6 months after implant placement.

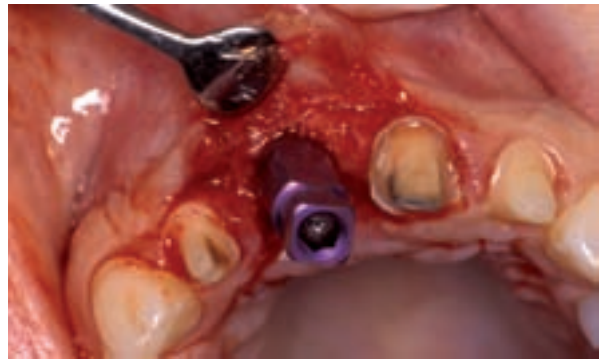


Fig. 24 Stage 2 implant uncovering with impression post in place.

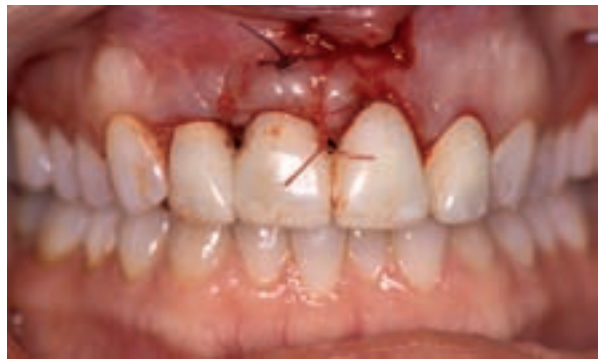


Fig. 25 Surgical site sutured with temporary abutments and provisional fixed acrylic bridge from nos 7–10.

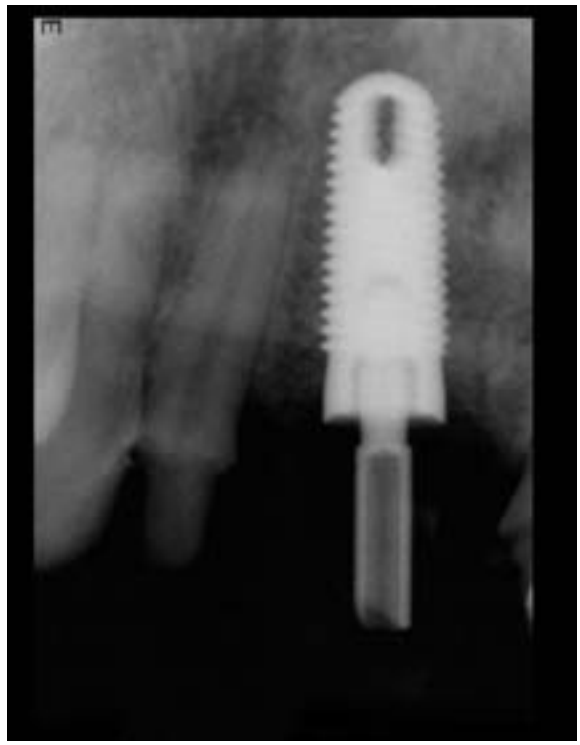


Fig. 26 Radiograph of implant with temporary crown. Note the vertical bone height of the surrounding bone.

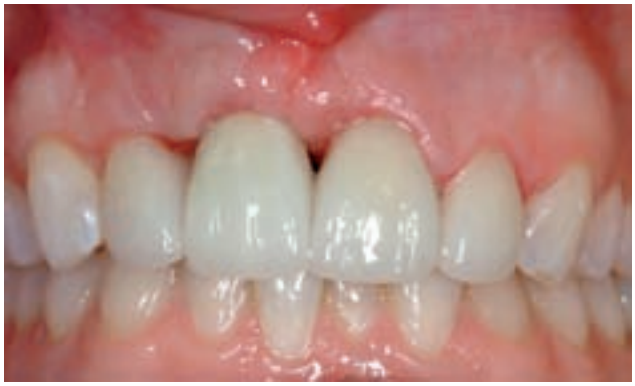


Fig. 27 Facial view of the final restoration in place at 6 weeks.

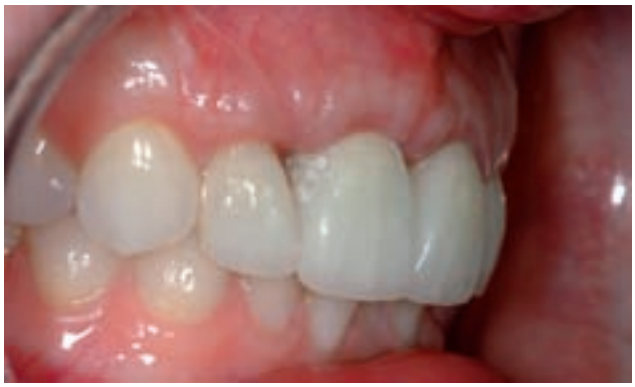


Fig. 28 Lateral view of the final restoration in place at 6 weeks. Note the natural-looking soft- and hard-tissue profile.

Case 9: Treatment of implant malposition in the esthetic zone

Burton Langer DMD, MSCD and Laureen Langer DDS

A 35-year-old woman presented with two implants in tooth positions 6 and 7. The cosmetic disfigurement resulting from the implant restoration motivated her to seek a second opinion from a prosthodontist (Fig. 1)

Etiology

The prosthodontist referred the patient for a periodontal consultation regarding the feasibility of soft-tissue grafting or any other procedures that might augment the soft-tissue defect. Upon examination and co-consultation, it was determined that the etiology of the problem was related to the malposition of the two implants (Fig. 2). The implants were in severe labial version, the clinical crown height was excessive, and there was a complete loss of keratinized gingiva on the buccal aspect. It was ascertained that placement of angulated abutments could not correct the cosmetic defect as it would

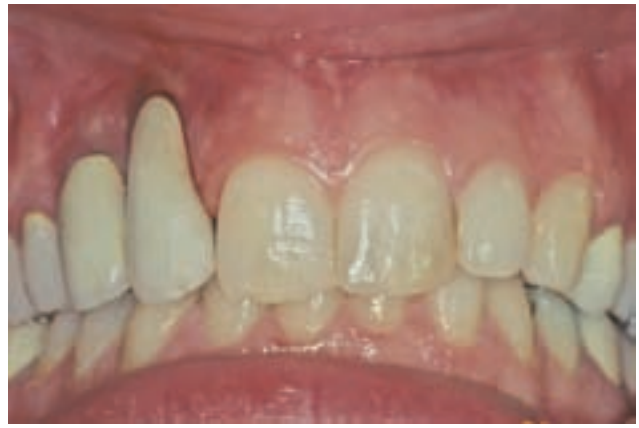


Fig. 1 Preoperative view of patient, who had two implants placed in tooth positions 6 and 7. The cosmetic appearance of the restoration on the implants resulted in an unfavorable result for the patient.

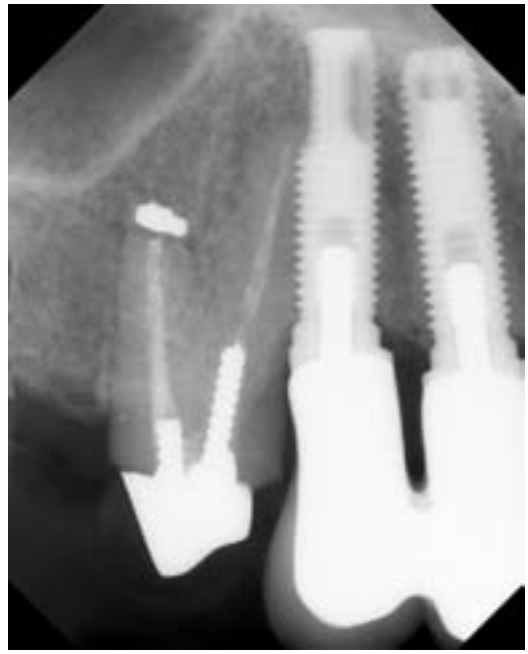


Fig. 2 Preoperative radiograph showing the two restored osseointegrated implants.

have been extremely difficult to realign the axial position of the implants. The patient was so unhappy with the esthetic result that she was willing to have the implants redone.

Prevention

If this case were to be done today a computer axial tomographic (CAT) scan and surgical stent would have been used. These would have aided in the diagnosis and placement of the implants in proper position. To avoid this problem, the surgeon should have placed the two implants in line with the adjacent teeth. If there was not enough bone or keratinized tissue, it was incumbent on the clinician to create the proper soft- and hard-tissue

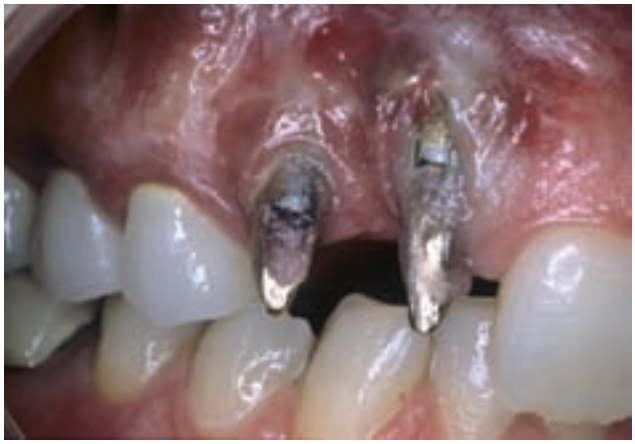


Fig. 3 The crowns were removed from the abutments. Both abutments were in severe buccal version.

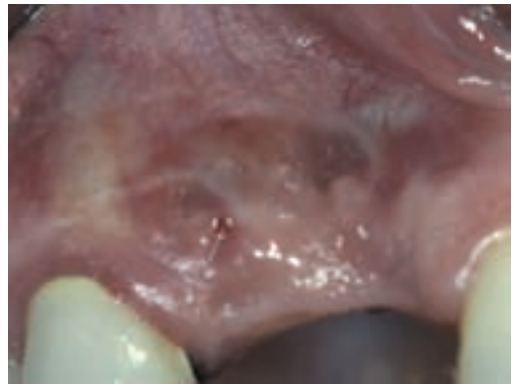


Fig. 5 The tissue was allowed to prolapse into the implant sites and within 6 weeks the tissue had almost completely filled the area of the implants. Even the character of the tissue became more keratinized.

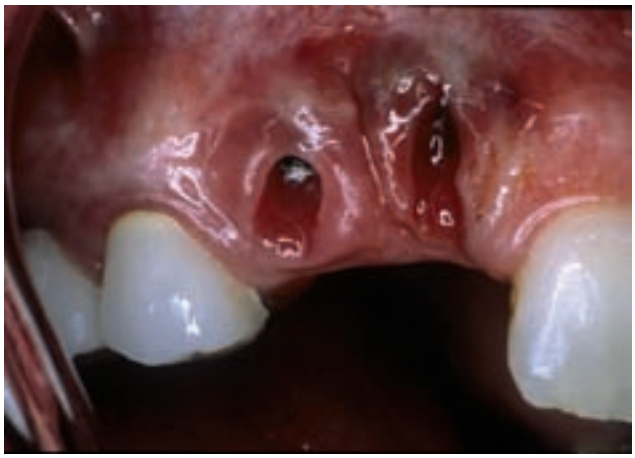


Fig. 4 The abutments were removed exposing the underlying implants which were countersunk and also in buccal version to the adjacent teeth.

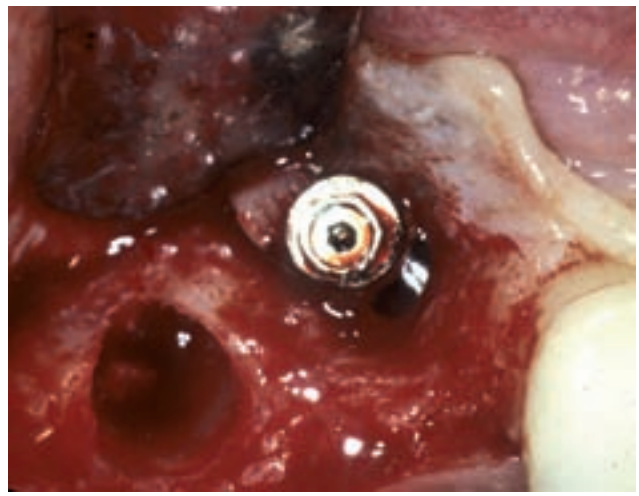


Fig. 6 The two implants were removed from the surrounding bone.

environment before implant placement. In this case the original anatomy of the ridge at time of implant placement was not known.

Treatment

The two crowns and abutments were removed and the patient was fitted with a removable appliance (Figs 3, 4). By removing the obstruction of the crowns and the abutments, spontaneous regeneration of the soft tissue was anticipated over the countersunk implants. Within 6 weeks the site was completely covered with new keratinized tissue (Fig. 5).

The original anatomy of the ridge at the time of the previous implant placement was not known; however, it appeared that the ridge was adequate to place properly aligned implants. An exploratory surgical procedure was performed after the 6-week healing period which verified that both implants were placed too far to the buccal. Soft-tissue grafting of implants in this position is rarely successful and generally continues to recede after placement of a restoration. It was decided that both implants should be removed and replaced.

Fully integrated implant explantation requires careful surgery so that the bone adjacent to the implant site is not damaged. This is especially important when the treatment plan calls for replacing the implants at the same surgical visit. A high-speed 170L carbide bur (Brasseler USA, Savannah, GA, USA) was used to reduce the width of the implants with minimal bone damage. The length of the bur was inadequate to extend to the apex of the implant without endangering the adjacent teeth. The smallest diameter trephine that would fit around the altered implant body was then used to finish the osteotomy. Closer to the apical area, an elevator was used to separate the implant from the apical bone. It is usually possible to loosen the implant once the osteotomy cut is within a few millimeters from the apex of the implant (Fig. 6).

The new implants were placed using the palatal cusps of the adjacent teeth as a visual guide (Fig. 7). This positioned the implants in the area that had the best bone and alignment for the future restorations. Demineralized freeze-dried bone allograft and an absorbable membrane were used to augment the buccal bone profile (Figs 8, 9) (University of Miami Tissue Bank, Miami, FL, USA). The membrane used was a demineralized freeze-dried laminar allograft (Pacific Coast Tissue Bank, Los Angeles, CA, USA). Primary closure was attained by slightly extending the vertical incision at the proximal line angle of the adjacent tooth. Since the tissue had time to prolapse onto the implant sites before the surgical visit, there was minimal need for tissue advancement. The flap was sutured with 4.0 silk interrupted sutures (Ethicon, Johnson and Johnson Co., Somerville, NJ, USA) (Fig. 10). The removable appliance was reinserted immediately after the surgery. Although any removable appliance always runs the risk of creating transmucosal overload, this can be avoided by countersinking the implants and relieving the appliance. Signs of tissue impingement must be monitored, and if found, corrected at follow-up visits.

A subepithelial connective tissue graft was performed 2 months after the initial surgery to thicken the keratinized tissue on the buccal. The healing abutments were placed after 6 months. When the patient returned to the prosthodontist 2 weeks later, plastic impression copings were placed on the two implants and the removable appliance was converted into a fixed provisional restoration (Figs 11, 12). With the implants in a more palatal position the restorative dentist gained additional thickness for porcelain on the buccal cusps. At this provisional stage the patient could appreciate the positive esthetic change that would be realized in the final fixed restoration.

The final screw-retained porcelain fused to metal restoration was completed within a few months and the patient was very satisfied with the esthetic outcome. The

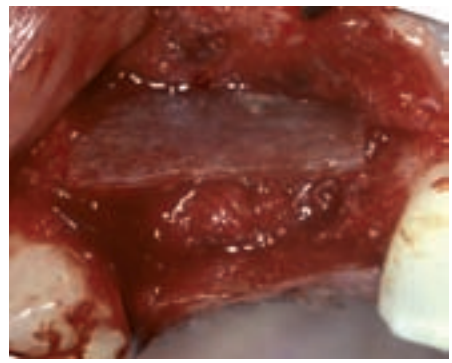


Fig. 9 A piece of demineralized laminar bone allograft was placed over the particulate graft.

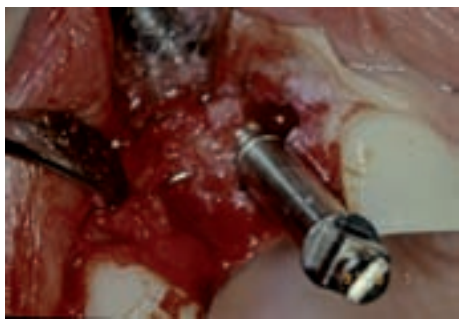


Fig. 7 Two new implants were inserted in line with the adjacent teeth.

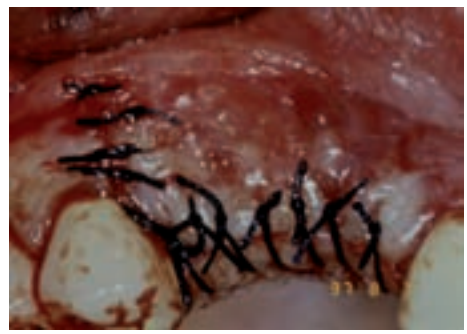


Fig. 10 The gingival tissue was closed over the implant site.

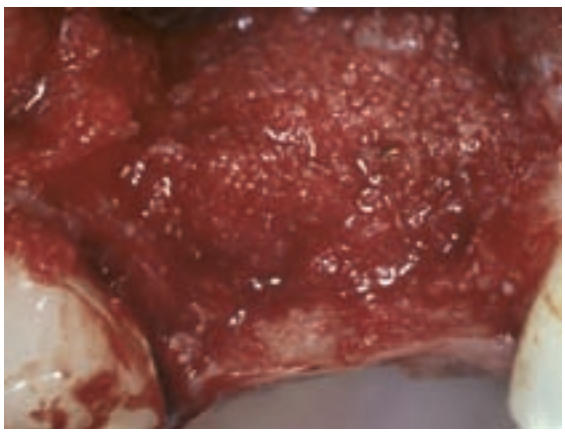


Fig. 8 The buccal bone was grafted with demineralized freeze-dried bone allograft.

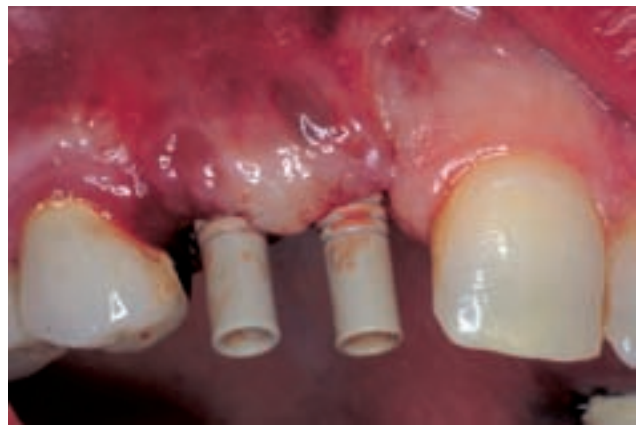


Fig. 11 After 6 months the area was uncovered and the removable appliance was converted into a fixed provisional restoration.

prosthetic treatment was performed by Dr Jonathan Ferencz. At the 8-year radiographic and 10-year clinical follow-up visits there had not been any significant soft- or hard-tissue changes (Figs 13, 14).

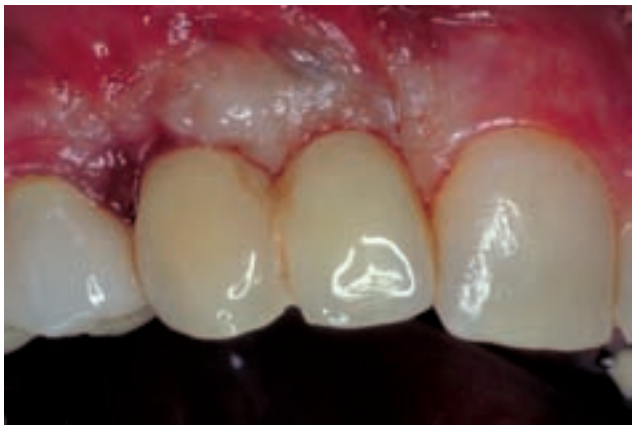


Fig. 12 The provisional restoration seen from the buccal aspect.

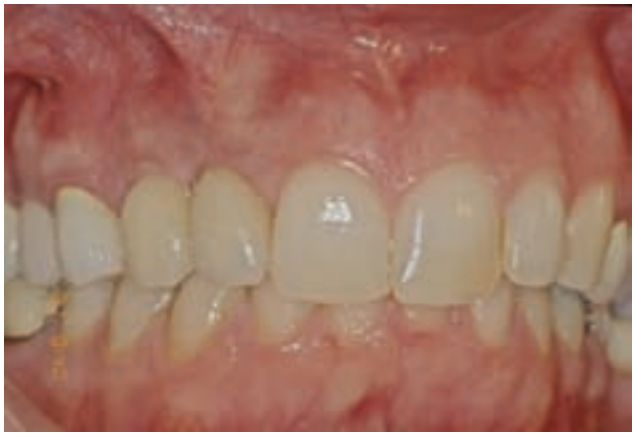


Fig. 13 The final porcelain implant restoration in place showing esthetic compatibility with the adjacent teeth.

Fig. 14 Radiograph of the implant restoration 8 years after the final prosthetic restoration.

Case 10: Treatment of a malpositioned implant in the esthetic zone

Stuart J. Froum DDS and Jeffrey R. Lemler DDS

The patient was a 28-year-old woman who presented with an abscess, pain, and exudate on the buccal aspect of the maxillary lateral incisor area (Fig. 1). Her chief complaint was that "my implant is causing my gums to bleed and abscess". Her medical history was unremarkable with no medications currently being taken and no history of allergies. An implant in the left lateral incisor area was placed several years before she presented and remained submerged. She was told by her former dentist that by placing this implant she could avoid having to restore the left central and left canine teeth. However, when it was determined that the implant "could not be restored" by her dentist a lateral incisor pontic was bonded to the left central and canine using a composite restorative material. Beginning 1 year later abscesses started occurring on the buccal aspect of the implant. Two surgeries were done by the surgeon who placed the implant to try to "clean out the infection". She later had a gum graft which, according to the patient, she was told "did not take". She had been on three different antibiotics over the last several months, each for 2–3 weeks, in an effort to resolve the abscess. Over the last few months the patient reported noticing that the "teeth that were connected over the implant were loosening" and she felt movement of the fixed restoration when she bit down or put her tongue against the teeth. A clinical examination was performed and periapical radiographs were taken

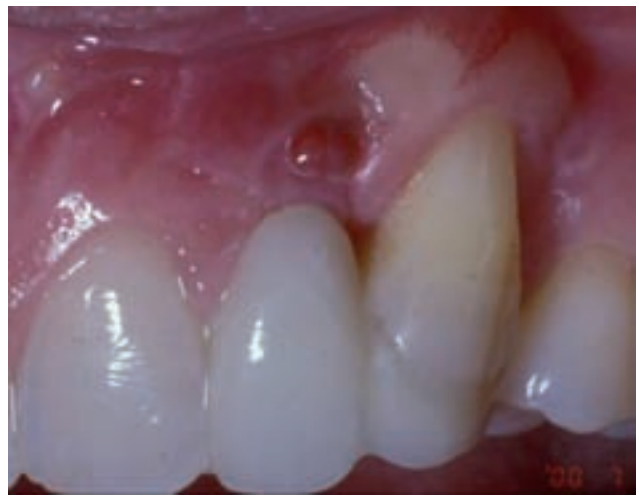


Fig. 1 Buccal abscess on the maxillary left lateral incisor implant.

(Fig. 2a, 2b). Probing of the left central incisor and canine teeth revealed 7–9 mm probing depths on the distal and mesial aspects of these teeth, respectively. The central incisor had class III and the canine class II mobility, respectively. Upon light percussion the patient reported pain on the central incisor tooth.

Etiology

The complication seen in this case was related to the malpositioned placement of the implant. The implant was mesially inclined with the implant platform several millimeters apical to the ideal position, which should have been 2–3 mm apical to the gingival margin of the adjacent central incisor. The implant appeared to be in contact with the central incisor root (verified postextraction of the central incisor). The mobility and bone loss on the central incisor made it a weak abutment. Therefore, in essence, the left cuspid was supporting a two-pontic cantilever splint. This, combined with the inflammation in that area, caused by periodontal disease around the left canine, resulted in increased mobility of this tooth.

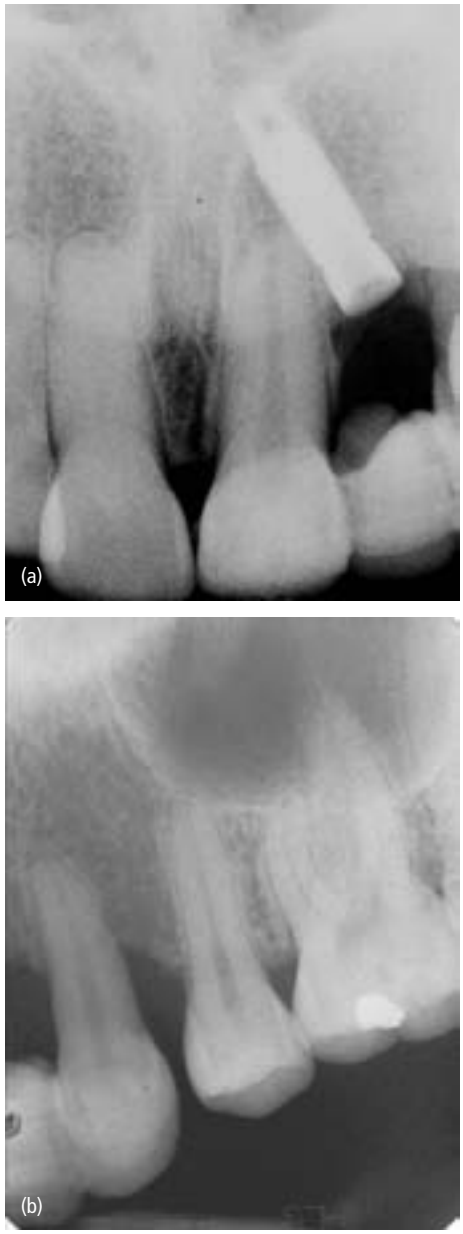


Fig. 2 (a, b) Radiograph of malpositioned submerged implant under a three-unit composite splint from left central to left canine.

Prevention

Correct implant positioning using a surgical stent created from an ideal wax-up could have helped guide the implant into the proper position. Use of directional indicators during the osteotomy would have helped guide the clinician in redirecting the positioning of the 2 mm drill at minimum depth (7 mm), allowing the desired osteotomy and positioning of the implant. The malpositioned implant should have been removed on the day of placement and either replaced with a correctly positioned implant or the site restored, and after healing, a delayed implant placement protocol used

Treatment

The patient was informed that the left central and left canine teeth were hopeless and would be extracted, and explained that if the implant was salvageable it would be submerged and kept as a "sleeper". The patient was informed that if at the time of flap reflection and extraction of the two teeth the implant was found to be at risk for continued disease, it would also be removed. She was also informed that in either scenario a combined hard- and soft-tissue defect would result which would probably require several surgeries to treat. With the patient's consent, treatment was rendered. Before surgery the patient was referred back to her new restorative dentist to prepare an immediate clasp partial removable denture to replace teeth numbers 9–11. When the partial denture was ready the patient presented for surgery. She was premedicated with 500 mg of amoxicillin three times per day beginning 1 day before surgery. This was done to obtain an adequate blood level since the area was still actively purulent and had bleeding on light probing. The 500 mg of amoxicillin was continued, three times a day, on the day of the surgery and for 1 week after surgery.

Surgery consisted of reflection of a full-thickness flap from tooth numbers 8–11 and extraction of the left central incisor and cuspid teeth (Fig. 3). Both teeth had lost their buccal plates of bone before extraction. The left central incisor root showed damage on the distal aspect, confirming the contact with the implant. The implant in the lateral position (10i) had mesial and buccal bony defects that probed 10 mm (Fig. 4). The platform had

been cut down previously. Based on these findings, submerging the implant was ruled out as an option. A narrow pointed diamond bur (170L) was used with high speed and copious irrigation to cut a channel around the implant. The internal threads and platform were damaged during the previous surgeries when an attempt was made to reduce the exposed aspect of the implant.

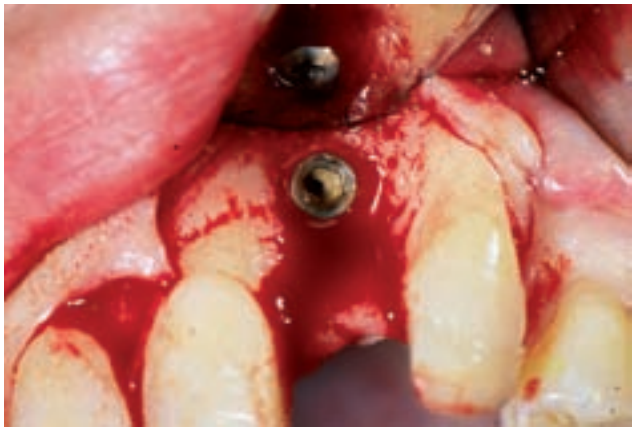


Fig. 3 Reflection of a full-thickness flap exposing the bone loss on teeth 9 and 11 and the malpositioned no. 8i implant.

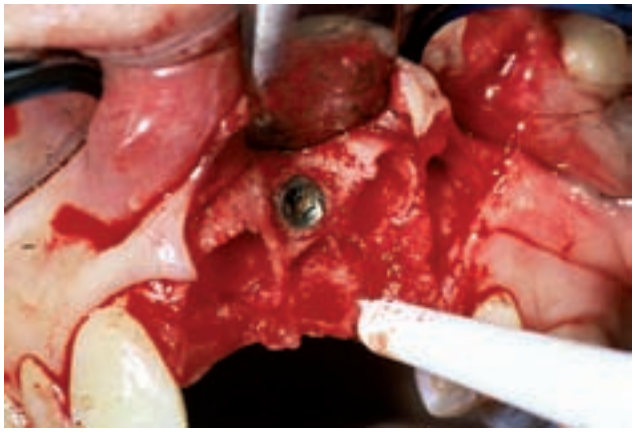


Fig. 4 The area after extraction of the left central incisor and canine teeth.

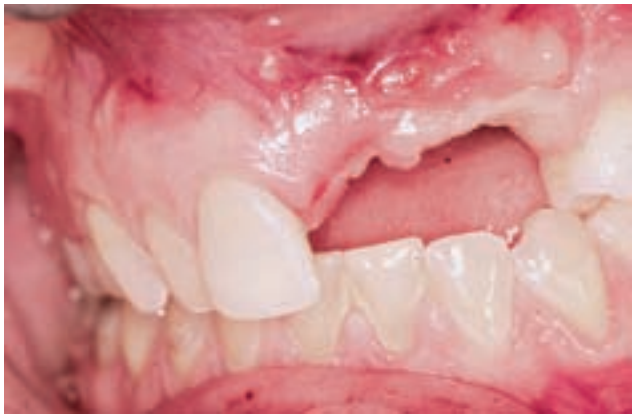


Fig. 5 The combination vertical and horizontal defect 3 months after extractions.

Therefore, the implant could not be reverse-torqued out and was extracted with forceps. The site was débrided and the flap closed. Because of the infection present around the implant, no ridge augmentation was attempted during this surgery. Healing progressed, but 3 months later the area displayed a combined horizontal and vertical 15 mm defect (Fig. 5)

Treatment consisted of three separate surgical procedures. The first procedure, designed to augment the bony defect, was performed 3 months after teeth/implant removal. A full-thickness flap was reflected from maxillary right to left second premolar teeth with vertical incisions distal to the second premolar teeth. The bony defect was débrided of all soft tissue and the flap reflected to the nasal sinus (Fig. 6). An oral–nasal communication was present which was caused by the implant removal. The buccal bone was decorticated with a no. 1 round bur. Two 14 mm bone screws (Osteotomed; 3i, Warsaw, IN, USA) were placed in the crest of the defect with 8 mm of each screw exposed (Fig. 7). The screws were used to support the graft material and membrane. The graft material used, consisting of 2 g of mineralized and demineralized bone allograft with a plasticizer

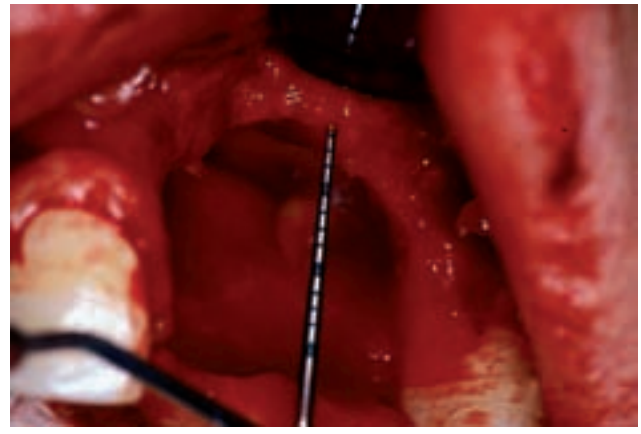


Fig. 6 The exposed osseous defect with a 10 mm vertical bone loss.

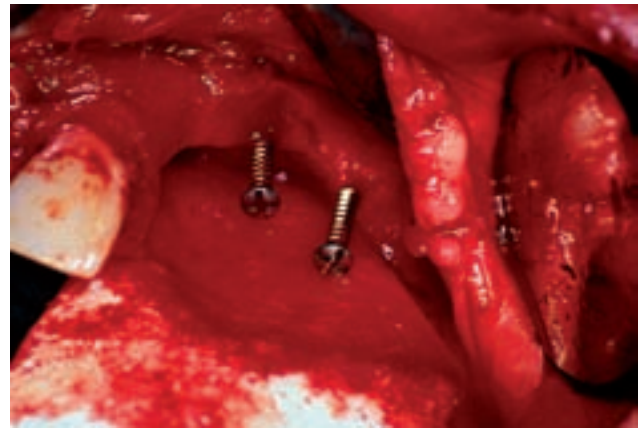


Fig. 6 The exposed osseous defect with a 10 mm vertical bone loss.

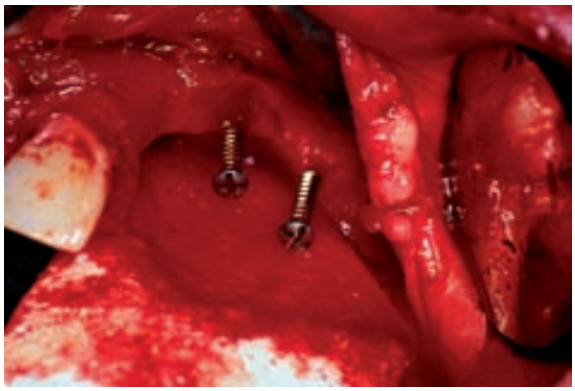


Fig. 7 Two bone screws placed in the defect to support the graft material and membrane.

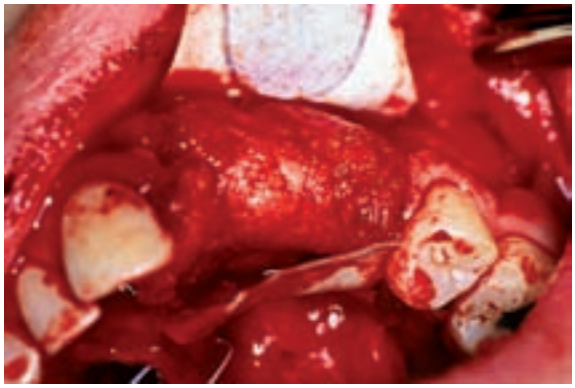


Fig. 8 The graft material contoured to fill the defect. A non-absorbable membrane is tacked and reflected before covering the graft.

(Regeneform; Regeneration Technologies, Alachua, FL, USA), was heated and molded to reconstruct the ridge (Fig. 8). Two non-absorbable ePTFE membranes (Goretex Oval 9; W.L. Gore & Associates, Flagstaff, AZ, USA) were contoured to cover the graft material and secured with ten buccal and two lingual tacks (Ace tacks; Ace Surgical Supply Co., Brackton, MA, USA) (Fig. 9).

These membranes were contoured to repair the oral antral fistula. Periosteal releasing incisions were made and the flap advanced to cover the graft. Vertical mattress continuous non-absorbable sutures (Goretex, W.L. Gore & Associates) were used to close the flap with no tension. Absorbable sutures (4.0 chromic, 4.0 monocril; Ethicon, Somerville, NJ, USA) were used to close the vertical incisions. The patient was instructed to leave the partial denture out and use an Essex appliance for 2 months. At that time the partial denture was adjusted and relieved to avoid all pressure on the surgical site. Six months later, under intravenous sedation, a similar flap was reflected and the membranes, bone screws, and tacks were removed. Following this a second augmentation was performed with the same graft material, which was covered with a double layer of two absorbable collagen membranes (Bio-Gide; OstheoHealth, Shirley, NY,

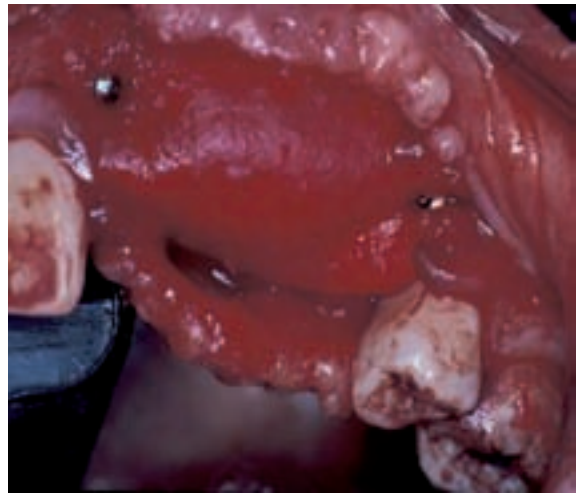
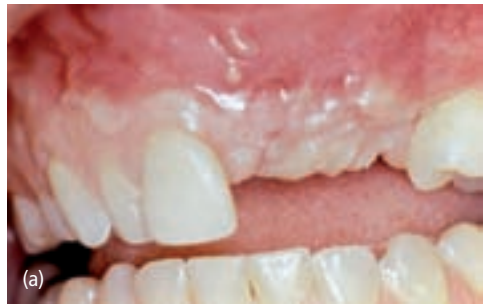


Fig. 9 Two non-absorbable membranes placed to cover the graft and stabilized with tacks.



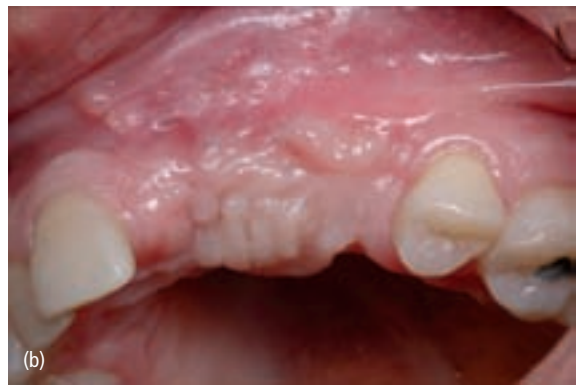


Fig. 10 (a, b) Healing after a second bone augmentation and a subepithelial palatal connective tissue graft. Note the augmented horizontal and vertical ridge with adequate volume of keratinized tissue.

USA) with tacks and absorbable sutures extending from the buccal periosteum to lingual flap. The purpose of these tacks and sutures was to immobilize the membrane and hold it against the graft. The flap was similarly sutured as in the first surgery.

Seven months postsurgery a subepithelial connective tissue graft from the palate was performed to re-establish the buccal vestibule and increase the zone of keratinized tissue. The area healed uneventfully (Fig. 10a, b). Nine months later, and under local anesthesia, a flap was

reflected from the right central incisor to left second premolar. Vertical incisions were made on the distals of the incisor and second premolar teeth. A flap was reflected and using a surgical guide two 3.5 × 13 mm implants were placed (Nobel Replace Select; Nobel Biocare, Yorba Linda, CA, USA) in the left lateral and canine areas (Fig. 11). In an attempt to obtain the best esthetic result, and because of a large incisive foramen in the area, the left central was planned as a cantilevered pontic (see Chapter 12). As part of the surgery previous tacks were removed and the same graft material was placed over the buccal aspect of the implants. The implants were used as tent poles to establish space for additional vertical augmentation. The graft was covered with two absorbable collagen membranes (Biomend Extend; Zimmer, Warsaw, IN, USA; and Bio-Guide; Osteohealth, Shirley, NY, USA) which were necessary to cover the entire graft and implants. The membranes were secured with bone tacks (Fig. 12), and the flap was advanced and sutured without tension (Fig. 13). Four months later the implants were exposed with gingival punches to avoid full flap reflection and the healing abutments were placed. The patient was immediately referred to the prosthodontist for temporization. Two months later crown lengthening was performed under local anesthesia on the maxillary right canine, lateral, and central incisor teeth. Eight weeks later final impressions were made and a three-unit implant-supported fixed restoration was completed (Fig. 14). The patient has been seen every 2–4 months for maintenance. The final restoration, now 7 years postcompletion, shows the soft tissue and bone to be well maintained and the patient is pleased with the esthetic results (Fig. 15). All prosthetics were performed by Dr Lawrence Calagna (private practice, New York City).

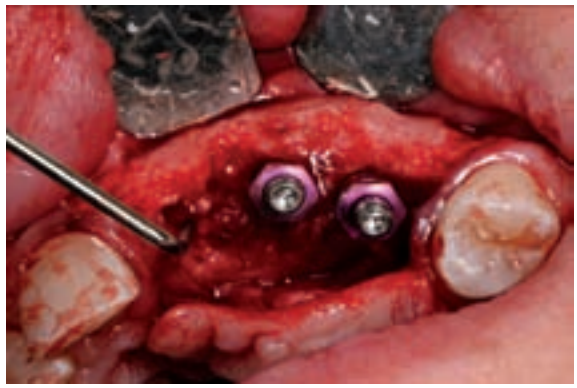


Fig. 11 Two implants placed in the left lateral and cuspid areas. Note the location of the incisive foramen.

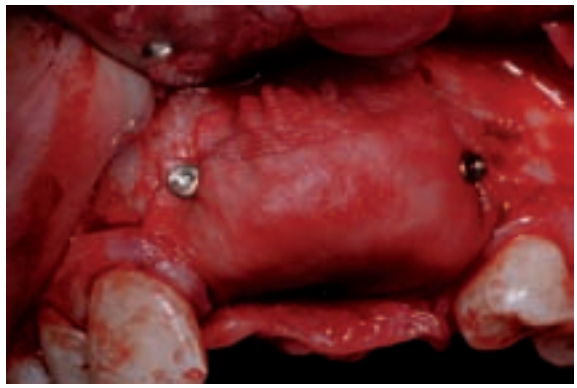


Fig. 12 At the time of implant placement, an additional buccal augmentation was performed with a graft and an absorbable membrane, which was stabilized with bone tacks.

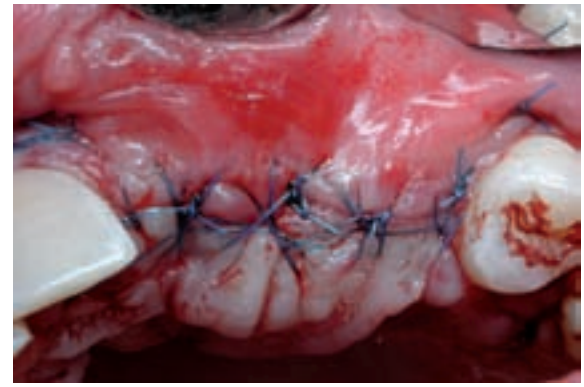


Fig. 13 The advanced flap was sutured with absorbable sutures without tension.

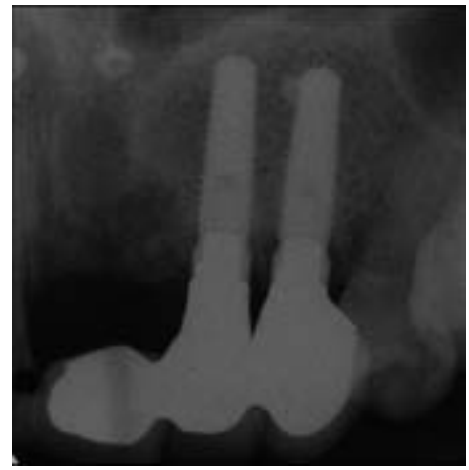


Fig. 14 Radiograph of the three-unit final implant-supported restoration with a cantilevered central incisor pontic.

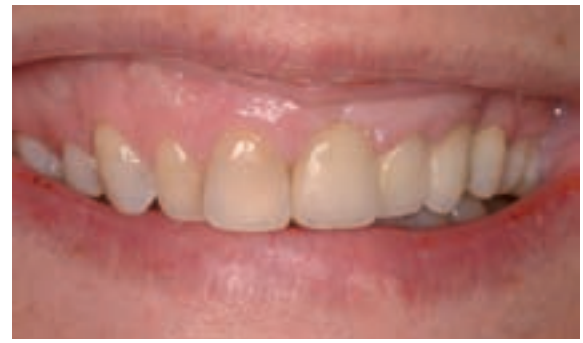


Fig. 15 Final restoration 7 years postcompletion.

Index

Note: Locators in *italics* denote tables and figures (when outside locator ranges)